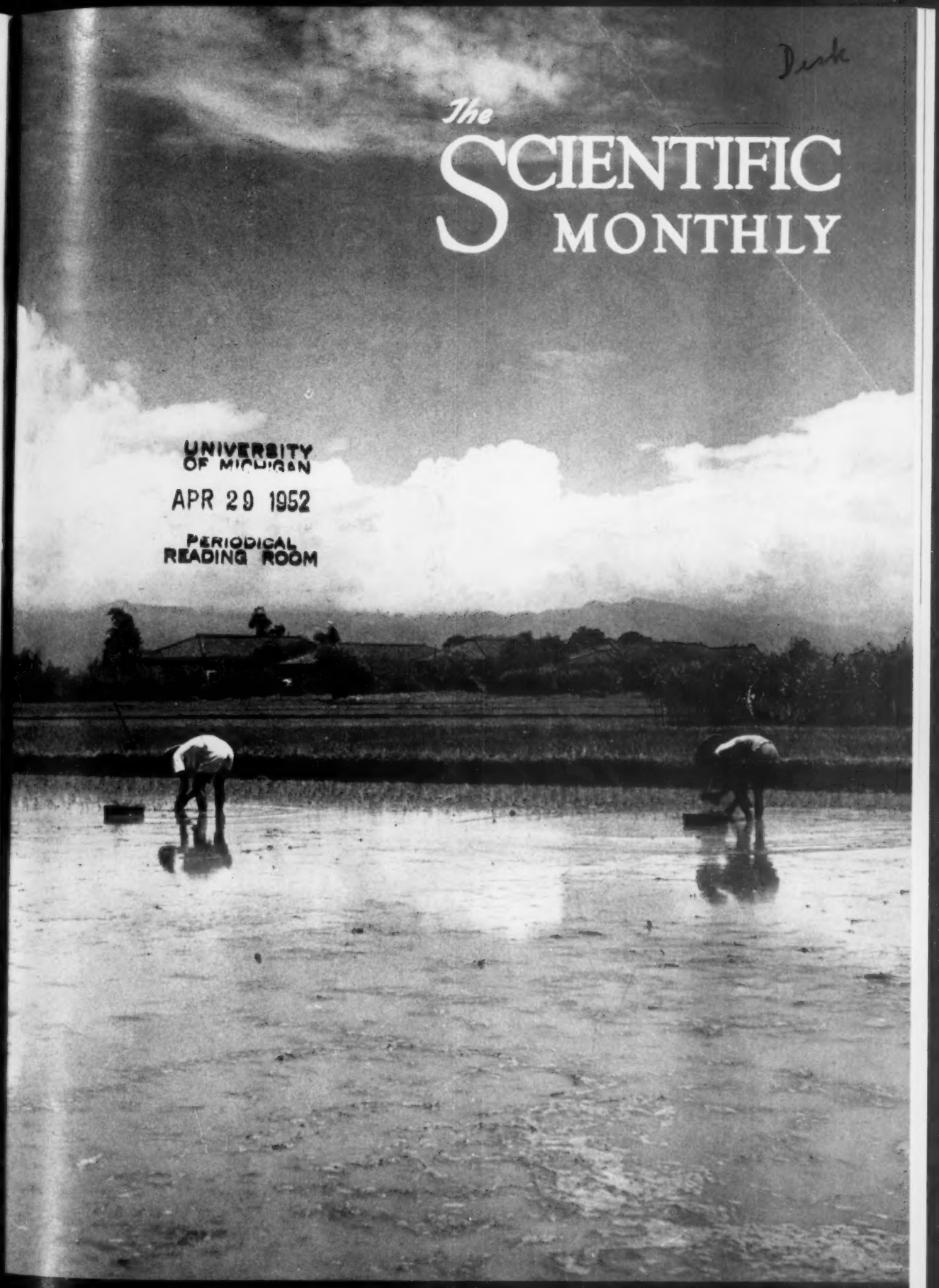
joining
Boulder
so, the
s of the
ing con-
s of the

ng, and
be wel-
rnished
, geolo-
nation,
current
re have
l indus-
of the
llations,
f active
science.
ill thus
elcome.

THLY



UNIVERSITY
OF MICHIGAN
APR 29 1952
PERIODICAL
READING ROOM

OL. LXXIV NO. 5 MAY 1952

plotting the field afar

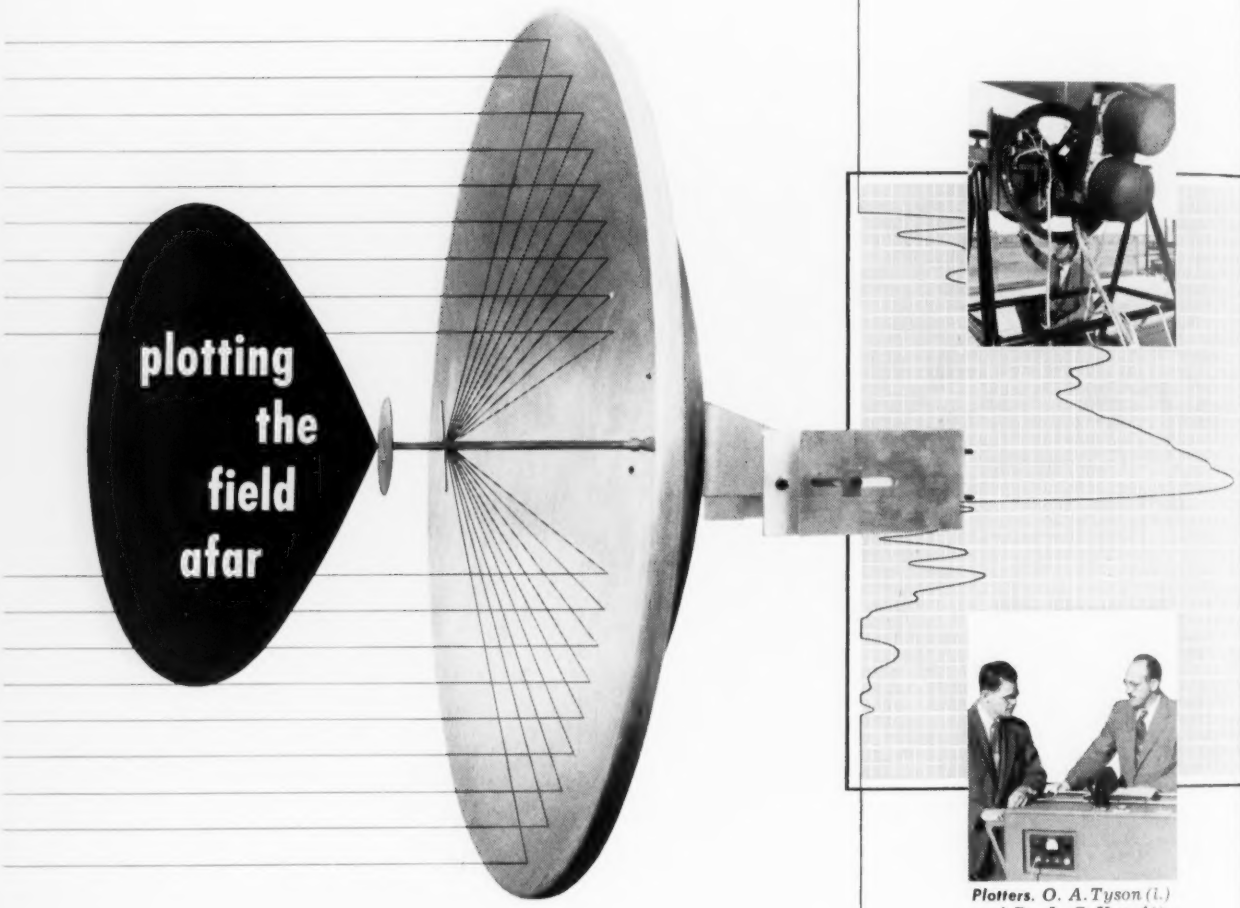
Plotting the radiation pattern of a microwave antenna is typically time consuming and laborious. For some time, workers in this field have felt a need for a continuous non-manual means of performing this operation. The extensive microwave activities of its Research and Development Laboratories have created at Hughes a special interest in such automatic pattern-measuring equipment.

The first automatic machines that were at all accurate were of the fixed location type and weighed nearly a ton. The new Hughes recorder weighs just one hundred pounds, is more accurate, and has higher writing speeds than the earlier machines. Its recording range covers 80 decibels in the audiofrequency spectrum. The writing speed is approximately 25 inches per second, with an 8"x11" plot, and the abscissa or angle scale is controlled by an electrical take-off system.

In the field of microwave measurements, this machine assists in determining many things—such as the correct shape of reflectors and the proper location of feeds. The development of such improved laboratory tools is an interesting by-product of a large research activity, such as that conducted by the 3500 men and women of the Hughes Research and Development Laboratories.

The growing requirements of both the commercial and military electronics programs at Hughes are creating new positions within the Hughes Research and Development Laboratories. Physicists and engineers who are interested are cordially invited to address correspondence to:

Hughes Research and Development Laboratories • Engineering Personnel Department • Culver City, Los Angeles County, California



***Plotters.** O. A. Tyson (l.) and Dr. L. C. Van Atta worked together in developing this new machine at Hughes.*

THE SCIENTIFIC MONTHLY

VOL. LXXIV MAY 1952 No. 5

Contents

Taiwan Farmers Transplant Young Rice Shoots . . . . . Cover
(ECA photo)

On the Nature of Scientific Law . . . . . *Laurence J. Lafleur* 247

Food Production and Administration in Taiwan . . . . . *T. H. Shen* 253

Architecture of Herbaceous Plants . . . . . *Lora Mangum Shields* 269

Science Teaching in Senior High School . . . . . *S. R. Powers* 273

Petroleum—Then and Now . . . . . *Paul D. Foote* 280

Mysterious Crater Elegante . . . . . *Allan O. Kelly* 291

Comparative Vertebrate Physiology . . . . . *F. H. McCutcheon* 297

Science on the March:

Who Gets the Grass—Man or Beast? . . . . . *Charles W. Johnson* 303

Social Research in World Affairs . . . . . *Kenneth L. Heaton* 304

Book Reviews by *R. Tucker Abbott, Arthur A. Allen, J. M. Cage, Huntington Cairns, Ernest A. Engelbert, Joel W. Hedgpeth, George F. J. Lehner, James C. Malin, W. M. Mann, Arthur A. Meyerhoff, P. S. Palmer, Gilbert M. Smith, Marjorie B. Snyder,* and *A. V. Wolf* 308

Association Affairs 314

GLADYS M. KEENER, Executive Editor

EDITORIAL BOARD OF THE AAAS

(Terms expire June 30, 1952)

HOWARD A. MEYERHOFF, Chairman
WILLIAM R. AMBERSON
BENTLEY GLASS
K. LARK-HOROVITZ
LORIN J. MULLINS
WALTER J. NICKERSON

F. A. MOULTON, Advertising Representative

Established 1872 as *The Popular Science Monthly;* since 1915 an official publication of the American Association for the Advancement of Science.

Publication office, Business Press, Inc., 10 McGovern Ave., Lancaster, Pa. Orders for subscriptions and requests for change of address should be directed to the Circulation Department, A.A.A.S., 1515 Massachusetts Ave., N.W., Washington 5, D. C. Subscriptions: $7.50 per year; single copies 75 cents. Four weeks are required to effect change of address.

Address all correspondence concerning editorial matters and advertising to THE SCIENTIFIC MONTHLY, 1515 Massachusetts Ave., N.W., Washington 5, D. C. The editors are not responsible for loss or injury of manuscripts and photographs while in their possession or in transit; all manuscripts should be accompanied by return postage. The American Association for the Advancement of Science assumes no responsibility for the statements and opinions expressed by contributors.

Copyright, 1952, by the American Association for the Advancement of Science. Entered as second-class matter at the Post Office at Lancaster, Pa., December 30, 1947, under the Act of March 3, 1879. Acceptance for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2) Section 34.40 P.L. & R. of 1948. Indexed in the *Reader's Guide to Periodical Literature.* The A.A.A.S. also publishes SCIENCE. Subscription and advertising rates on request.

Cable address: ADVANCESCI.

Science and Technology

(From the Month's News Releases)

Camper's Delight

Plastic sheeting made into folding water buckets, drinking cups, wash basins, and dishpans for campers will reduce the pack load. The drinking cup can be used for hot coffee, and the bucket, equipped with handles, can be used for a number of things besides water. A plastic hot or cold carry-all designed for picnickers might also be used by campers, as it will keep food cold for about 15 hours. Up to a dozen 12-ounce bottles and the ice to refrigerate them, up to 12 quarts of hot soup or other warm food in suitable containers, or 300–400 ice cubes may be carried.

Operation Flare

The Army Engineers, in cooperation with the Army Map Service, have successfully tested a new, rapid method that makes use of airborne stations to supply basic data for mapping and field artillery fire control. An airplane equipped with signal lights and flares provides visual targets for ground parties carrying theodolites. Cameras photograph the horizontal angular reading of the instrument while tracking the light or flare, and simultaneous readings from three fixed, known locations and three unknown are made by tripping the shutters at the same instant by remote control in the plane. By trigonometric computation the data are extended to the unknown locations.

Packaged Doors

A door and frame unit that can be hung by even a semiskilled carpenter in about 20 minutes is adjustable for wall thicknesses from 4¼ to 5½ inches and comes in all standard door sizes. A packaged roller door unit has two revolving roller guides operating in a head track, thus doing away with hard-to-install, noisy overhead tracks. It comes in a wide variety of woods, two styles, and standard widths. Floor tracks are not required.

Deodorizer

A small lamp that emits about three times more ozone-producing ultraviolet than previous deodorizing lamps quickly eliminates unpleasant odors from cooking, smoking, dampness, mildew, and perspiration. The 3½-w, 12-v bulb lasts six months when operated 24 hours a day from a standard 110-v, single-phase, a-c source. Suitable wall fixtures containing a built-in control device to limit current and voltage are available.

High-speed Copying

An electronics engineer has developed a special-purpose cathode-ray tube for use in applications requiring high-speed visual presentation of information on a direct-viewing screen or permanent reproduction on ordinary newsprint or other low-cost material. Among general applications are the data conversion and tabulation of analog or digital information, high-speed communications, monitoring and message display equipment, and computer read-out.

A photographic system still in the research development stage involves the use of a paper matrix coated with a slow but light-sensitive emulsion. In a demonstration of the experimental unit, three positive, ready-to-use copies of a letter were made in just 90 seconds.

Handmade Paper

Teachers of chemistry, printing, industrial processes, occupational therapy, and the arts will be interested in a packet illustrating how to make paper by hand. A 5″ × 7″ piece of Fourdrinier paper machine wire is included, for use in the construction of a mold, which is a simple hammer-and-saw woodworking project. Ordinary kitchen utensils are the only other equipment necessary. Packets are 25¢ each.

New Body

A low-cost automobile body, molded in one piece of 0.2″ thick plastic, weighs only 185 pounds in a custom sports design. After a 3000-mile cross-country road test, a demonstration car was exhibited at the National Plastics Exposition in Philadelphia in March. Dent- and dustproof, it is at present available in only one design, which will fit a frame with a 100″ wheelbase.

Dental Research

Erling Johansen, fellow in dentistry at the University of Rochester School of Medicine and Dentistry, has developed an instrument that painlessly immobilizes small experimental animals such as rats, guinea pigs, and hamsters so that dental researchers can make close-up photographs of the minute processes of dental decay and periodontal diseases. It also makes possible the controlled application of chemicals to teeth and accurate studies of effects of toothbrushing. Although the new instrument is simple and inexpensive, manipulation requires training.

North American Philips Company is distributing a nylon angulator that holds X-ray film flat in the mouth. No more dentist's thumbs in your mouth, the company says.

Yum-Yum—Fall Raspberries

"September" is the name given to a new fall-bearing raspberry developed at the New York State Agricultural Experiment Station, Geneva. Not only does the plant bear fruit during the regular summer season, but early in the fall another crop may be gathered. Horticul-

---

Address a post card to Science and Technology, 1515 Massachusetts Ave., N.W., Washington 5, D. C., for further information about any item on pages iv and v.

turists and others who have tried September rate it as superior in quality, yielding ability, and freezing characteristics.

Precision Cleaning

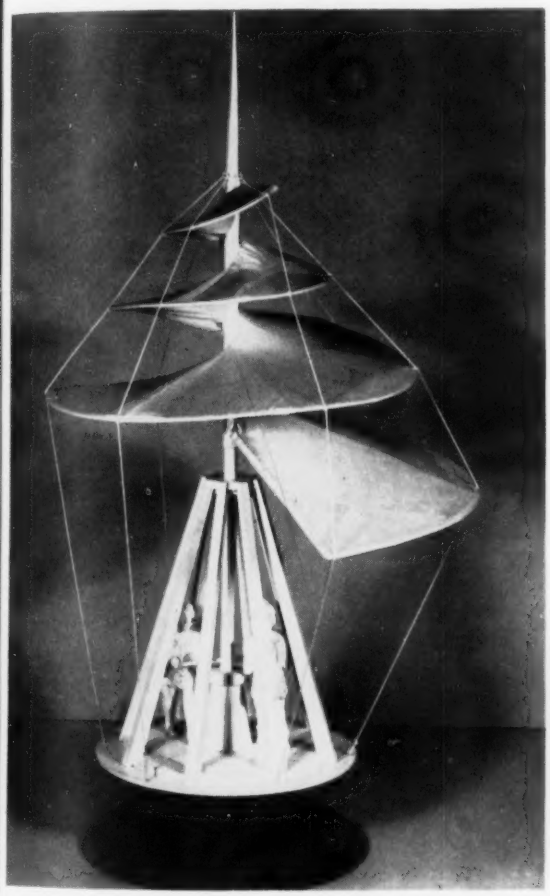
A machine designed for cleaning every kind of instrument, with small or large delicate parts, has been devised by the manufacturers of a watch-cleaning machine. Its use is recommended for cleaning time-clocks, meters, radio, television, typewriter, and screw machine parts, and bearings. It will also accommodate the new type parking meters without disassembling the entire train.

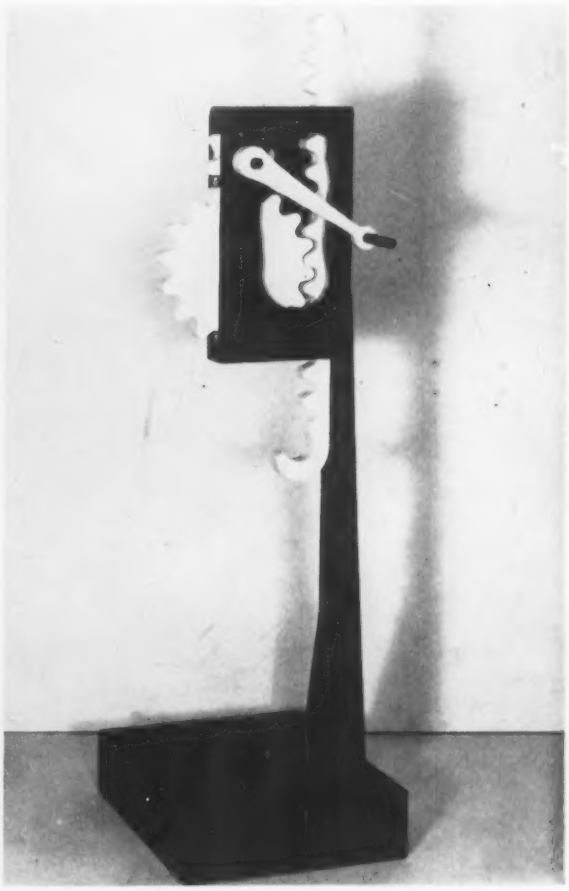
Portable Filter

A simple-to-operate demineralizer consists of a 6-, 8-, or 16-oz polyethylene bottle with a blended filter of deionizing materials inserted in the neck like a stopper. When the bottle is filled with ordinary tap water, one quick squeeze produces a stream of pure water—equal, so the manufacturer says—to that produced by triple distillation. The special filter, which changes color when it has been consumed, will produce up to 20 gallons of pure water, depending on local conditions. It's inexpensive.

Color Service

Monsanto Chemical Company's Plastics Division has retained Faber Birren, New York color authority, to do color research, especially the investigation of public buying trends and sales records. From his research, Monsanto will distribute to molders and fabricators periodic reports on color trends, with special studies on color problems for particular groups of products.





Leonardo did it first (cf. *Sci. Monthly*, **62**, 335 [1946]). On April 15, five hundred years ago, the versatile and inquisitive genius Leonardo da Vinci was born in the little town of Vinci. The great Italian painter, sculptor, architect, and engineer designed innumerable mechanical devices, many of them seeming to foreshadow later inventions. Among them was an aerial screw, with motive power to be supplied by a spring-driven mechanism to operate in the manner of modern clockwork (left above); and a contrivance for lifting weights, reminiscent of present-day automobile jacks (right). In 1938 the city of Milan held an exhibition of full-scale reconstructions made from Leonardo's original drawings, and the following year some of the models were displayed at Rockefeller Center. When World War II broke out, the exhibition was shipped to Japan, where it was eventually destroyed by enemy bombs. Roberto Guatelli, noted da Vinci scholar, under whose supervision the replicas were made, had accompanied the exhibit to Japan. After his return to the United States he constructed new, small-scale, working models from the original plans. This exhibit has been acquired by International Business Machines Corporation and is now being shown throughout this country and abroad.

NOW! "Easy Chair" MICROSCOPY with

BAUSCH & LOMB Dynoptic MICROSCOPES

A quick setting of the coarse adjustment . . . then *all* controls are operated with the hands *at rest* on the table. Fine adjustment is controlled by a knob only three inches above the table top; critical focus is more quickly, more easily achieved, with the operator completely relaxed. The hand moves easily from fine adjustment to mechanical stage knobs.

Comfort and convenience have influenced Dynoptic design throughout—providing the fatigue-free operation necessary for more thorough examinations over prolonged periods—assuring full benefit of *the finest laboratory microscope* ever made.

WRITE for a free demonstration and complete catalog literature. Bausch & Lomb Optical Company, 771–14 St. Paul Street, Rochester 2, N. Y.

Most Comfortable

B&L **THE WORLD'S FINEST LABORATORY MICROSCOPES**

THE SCIENTIFIC MONTHLY

MAY 1952

On the Nature of Scientific Law

LAURENCE J. LAFLEUR

Dr. Lafleur has contributed several articles to THE SCIENTIFIC MONTHLY *during the past ten years, the latest of which appeared last November ("Cranks and Scientists," 73, 285). The biographical notes accompanying that paper no longer apply in one important particular: Formerly associate professor of philosophy in Florida State University, Dr. Lafleur has recently become head of the Department of Philosophy at the University of Akron in his native state of Ohio.*

THE earliest concept of what we now think of as scientific law is to be found among the early Greeks. Its occurrence then was of the greatest historic importance, since it differentiated the Greeks as philosophers or scientists from the mythologically or pragmatically minded peoples who preceded and surrounded them. The spark they struck has remained alight for twenty-five centuries and has extended to more and more people until it is now shared by almost all mankind. This Greek concept was that the universe had a plan or pattern. To say that the universe has a pattern is to say that it is rational, and that every part of it fits into some over-all system; to say that it has a plan is to suggest that its pattern was consciously contrived by a superhuman being, and instead of a universal system we may refer to a universal scheme in the mind of this being. To the Greeks, law might be either of these two things, plan or pattern.

In addition, the Greeks made another distinction: insofar as the over-all pattern was thought of as a simultaneously presented whole, systematic connectedness like that of a painting or a cathedral, it was called *nous*, or reason. Insofar as it was thought of as involving direction, as in the case of conclusions derived from premises, it was called *logos*, from which both our name and our concept of logic were derived. The most important application of the notion of *logos* is to time, where the Greeks supposed that earlier events gave rise to later events in a pattern called cause and effect, and that the patterns or laws of causation themselves form a hierarchy, general laws being subsumed under still more general, just as individual events are subsumed under the former until at last all laws are seen to be derived from a single, all-embracing principle. Thus the Greeks laid down the two fundamental characteristics of all scientific investigation: the empirical investigation of the relationship of events in time, and the ascription of these events to principles, or laws, of the widest possible generality.

The Roman and medieval periods added little to scientific knowledge but had some contribution to make to the concept of law. Law came to be thought of quite definitely as plan and not as pattern, and the plan existed in the mind of an omniscient and omnipotent God. Hence the analogy with a plan in the mind of a human ruler becomes pronounced, and natural laws become thought of as legislated by God as legal regulations are enacted by a legislature. This notion became so thoroughly accepted that eventually it could be used

as an argument for the existence of God: where there are laws, must there not be a lawmaker? Once freed from the restrictions upon the concept of law prevalent in medieval times, it becomes obvious that the parallel between natural law and legislative law is a superficial one. A natural law describes what does in fact take place, a legislative law prescribes what the legislators wish to take place. A legislative law may be violated: a natural law never, for every so-called violation of or exception to a natural law is, properly considered, merely an exemplification of it. Finally, a legislative law carries a penalty for its violation, and the penalty itself may be avoided, whereas natural law, being impossible to violate, has no such penalty except insofar as one inaccurately thinks of unpleasant effects as the penalties for injudicious behavior, and these effects are unavoidable whenever the causes necessary to produce them have occurred.

Another way in which the medieval concept of natural law differs from the modern is that natural law was thought of as purposeful rather than as a blind *vis à tergo*. The universe, that is, was organized in terms of the purposes of God, and as these purposes revolved about the good will and destination of human souls, the position of matter was distinctly unimportant and subordinate. Thus it was not merely unprofitable to study the physical sciences, it might be in large measure impossible, for whenever the nature of matter produced a result contrary to the purposes of God, it was logical, and in a sense natural, that a miracle should occur. If miracles are sufficiently common, they may prevent the kind of scientific observation and successful prediction necessary to establish physical laws.

Modern Concepts of Natural Law

The modern concept grows out of the medieval by revolt, inspired in part at least by the rediscovery of Greek ideas. The characteristics ascribed to natural law in the first part of the modern period may be divided, more or less arbitrarily, into the following: natural law is thought to be universal, unitary, simple, self-evident, accurate, meaningful, and merely rational.

In saying that natural law is universal, we mean that the same laws apply in all places and at all times. To us, today, such a belief seems so inevitable that it is hardly worth mentioning, yet it was not always believed. Consider, for example, Swift's description, in *Gulliver's Travels,* of the island of Laputa, which floated over Balnibarbi by a law of nature that was peculiar to that region. Such a notion is fairly representative of the era of exploration, when nothing in a new land could surprise a traveler, who could report new physical, chemical, or geological laws as readily as a new biological species. Only a century ago, Edgar Allan Poe was supposing that the water at the South Pole obeyed different laws than elsewhere, and science fiction today offers many illustrations of the same idea. To turn from literature to science, it was not so long ago that astronomers were wondering whether the chemical elements known to us existed elsewhere than on earth, and even after spectroscopic investigations began to give us an affirmative answer, some doubts were engendered by the discovery and pseudo discoveries of helium, coronium, and nebulium. That natural laws might vary with time is an ancient notion indeed: alternate periods with contrary laws were proposed by Empedocles in the fifth century B. C., in much the same way as by Edgar Allan Poe in 1840, or today by occasional astronomers and physicists.

When we say that natural law is unitary, we mean that all laws are ultimately reducible to one, so that the progress of science consists largely in the reduction of a large number of laws to a smaller number. The best known and historically the most important case is Newton's combination of Kepler's laws of planetary motion and Galileo's law of falling bodies into the law of gravitation, although it was twice anticipated by Descartes, in his union of algebra and geometry into analytic geometry, and in his reduction of heat to the mechanics of particles. Combinations of this type have been made throughout the history of modern science, and continue to be made: Einstein recently proposed a project to reduce all the laws of physics to one.

In the early part of the modern period it was understood that natural laws were simple. For example, many laws state that one quantity varies directly or inversely as another, or as the square or other integral power of another. Another favorite form of law is one that asserts that events happen in such a way that a given quantity is maximized or minimized, and the most common form of all asserts the equality of two values, as the conservation of mass, energy, or angular momentum. If laws must be simple, it is possible to estimate the probability of scientific hypotheses in advance of experimentation. Let us assume, for example, that we know that light can be reflected, but have no knowledge of the laws of reflection. We can list possible laws, in order of descending probability, as follows: first, the angle of the re-

flected ray might be independent of that of the incident ray, and be always perpendicular to the surface; second, it might occur in a plane through the incident ray perpendicular to the surface, and such that the angle of reflection is a fixed multiple of the angle of incidence, the most probable multiple being unity; third, it might occur in this plane so that the angle of reflection is a fixed multiple of the complementary of the angle of incidence, the most probable multiple again being one; fourth, the multiple involved in either of the two preceding cases might be a variable dependent upon the density, transparency, hardness, smoothness, or other quality of the reflecting surface, or upon the frequency of the light or its velocity in the medium in question; and last, the plane of reflection might be at a fixed angle to the one thus far considered, or at an angle dependent upon some quality of the reflecting material or the light. Only a slight amount of experimentation is then needed to determine which is the correct hypothesis; and a method of proceeding by elimination is also possible. This description of scientific procedure seems strained to modern ears, but it is precisely the one offered by Bacon, Descartes, and Mill, the one actually used by many early scientists, and one that is still occasionally exemplified in contemporary work.

If this is a true description of scientific law and scientific method, it also follows that the task of the scientist is an easy one that should not take too long to accomplish. Thus we find scientific optimism prevalent. Bacon proposed a cooperative effort to find out all about science in a very few years, Descartes had hopes of completing the task within his lifetime, and toward the end of the nineteenth century there was a strong feeling among scientists that the end was in sight, as far as general principles were concerned, and that the only task left for 1950 and later would be the encyclopedic one of working out and cataloguing the details of the various sciences.

Closely related to the simplicity of natural law is the notion of its self-evidence. After all, if the simplest possible law—all things being considered—is the true one, then when we know enough to recognize the utter simplicity of a certain principle, we know that it must be true regardless of the evidence. Thus, empirical evidence leads us to believe in the existence of a substance occupying space, or matter, and something that thinks and feels, or mind. It appeared self-evident to Descartes and his successors in science and philosophy that mind, being nonspatial, could not impart a spatial motion to matter, and that matter, being merely spatial, could not affect mind. Such views were and are held despite the patent fact that material events affect mental events whenever we observe, and that the reverse occurs whenever we conduct an experiment or act on a belief. This conflict between self-evident truth and empirical fact has had a long train of consequences in the histories of philosophy and of science—much too complex to deal with here—which has left scars upon both.

In saying that natural law is accurate, we mean that it is possible for man to discover real principles that describe precisely how objects behave. If the Newtonian law of gravitation is correct, then the force of gravitation varies inversely as the square of the distance—not within 1 per cent of this value but precisely; it operates in the direction of the center of mass, precisely and not approximately; and it functions in this manner always, not just most of the time or on the average. And, of course, if scientific laws are accurate, the assertion is implicit that they are mathematically formulable.

To say that scientific laws are meaningful is to say that each of the terms used in the statement of the law or in its mathematical formulation can be assigned a meaning that refers independently to the objective world. Thus, if Newtonian gravitation is given by the formula $F = G\frac{m_1 m_2}{d^2}$, the expression on the right-hand side of the equation is not merely a set of directions for finding the force; m_1 and m_2 represent the masses of the interacting bodies, d the distance between them, and G the constant of gravitation.

In saying that scientific law is merely rational, we mean that nature contains nothing except what can be explained by scientific laws of the type we have described. Thus, color is referred to quantitative variations in the vibration rate of light, and it is assumed that the quality of redness or blueness that we see does not characterize nature at all, but is only our subjective reaction to the really objective vibration rates. Reality itself is gray, or rather does not even possess the quality of grayness: it is without sweet or sour as much as without red or blue, and similarly lacks smoothness, sonorousness, heat and cold, beauty, goodness, and value.

These qualities, of being universal, unitary, simple (with attendant optimism), self-evident, accurate (and mathematical), meaningful, and merely rational, were believed to characterize natural law during the major part of the modern period. During the last century, however, many of them have

been doubted or even wholly discredited, mostly as the result of specific scientific developments, although in a few cases the change came from other sources.

Philosophic criticism is the principal reason for abandoning the notion that natural law is merely rational. For one thing, we cannot succeed in denying nature's possession of color and other qualities, for in the attempt to do so we inevitably call these qualities subjective and ascribe them to mind: mind, which is also natural, and a part of nature. Second, the distinction between the so-called primary qualities, size, shape, motion and the like, which we assume characterize the object, and secondary qualities such as color, which we consider purely subjective, appears to be an arbitrary one based on the circumstance that men rely more on sight and touch than upon the other senses. If a dominant species on some other planet relied principally upon hearing, would they not, as Haldane has suggested, choose a completely different set of characteristics as primary? And if the distinction breaks down, then we are faced with a dilemma that many scientists and philosophers find quite unpalatable. Either *all* qualities are subjective, so that true knowledge of the universe is impossible and we are forced into the scepticism of Hume or the phenomenalism of Kant; or all qualities are objective, and this valley is as objectively green and beautiful as it is broad and deep. Similar philosophic criticism has tended to discredit the belief that natural laws are self-evident; and the belief has also suffered from the recurrence of instances where the self-evident truth turned out to be no truth at all. It is difficult to maintain the view that natural law is meaningful when we observe that alternative explanations are frequently possible. Thus, the same line may be described in polar or Cartesian coordinates; the same light may be treated as a particle or as a wave; the interaction of massive bodies may be described in terms of forces or fields of potential; and so on. In these cases it seems unlikely that both the alternative sets of concepts refer to objectively existing entities. But the greatest blow dealt the notion that natural law is meaningful came from the extensive use of imaginary numbers in the analysis of electric circuits, and no objective equivalent of the imaginary constant has been found.

The Advancing Frontier of Science

Scientific optimism has died a natural death of old age; for if Descartes expected the supreme achievement to be made in a few decades back in 1637, the time has certainly run out, as it has run out on many similar expectations in the three hundred odd intervening years. Furthermore, each advance of science has left scientists with an increased appreciation of the extent of the unknown, so that today the existence of this sort of optimism is rare indeed, the only contemporary example of it that comes to mind being Einstein. The simplicity of scientific law is certainly hard to maintain in an age that has seen three progressively more complex formulations by Einstein, as well as some equally difficult theories in the realm of quantum mechanics. It is true that Infeld, for example, claims that Einstein's laws are simple, but he uses the word "simple" in an unusual sense, evidently meaning by it what we have called "unitary." And, finally, extensive experience of the revision of laws, and a revulsion of feeling from the earlier optimism, have led to the pessimistic denial of the accuracy not only of current, but also of all possible, laws.

After all these criticisms have been made, we find that the only conceptions of natural law that remain unchallenged are that it must be universal and unitary. To these two ideas contemporary science adds one that results from the denial of accuracy: the notion of law as approximation.

If we place two dots at random on a plane surface, we can draw a straight line through them, or derive an equation of the form $y = ax + b$, which represents this line. If we place N such dots on a surface, we may, in general, connect them by means of an equation of the form $y = ax^{n-1} + bx^{n-2} \ldots\ldots + k$; or we may use a lower order equation, say, a linear one, which merely approximates the positions of the dots, as is commonly done in statistics by the least squares method. If the number of dots is made infinite, as by taking a line drawn at random, or the coast line of the United States, or the graph of the temperature for a given period, then no equation would accurately represent it, since such an equation would require an infinite number of terms. Given such a line, say, a temperature graph, it may be approximated by a least squares line, or a quadratic curve, or a cubic one. We can imagine a meteorologist attempting to portray the daily temperature fluctuation as a quadratic curve and finding an equation of sufficient accuracy to satisfy his needs. A later meteorologist formulates a biquadratic equation, or perhaps an exponential curve, thus increasing his accuracy at the cost of increased complexity and difficulty of application. The contemporary scientist tends to visualize his science

in similar fashion: the scientific principles of seventy years ago were oversimplified; they were useful in their day but have now been superseded by more complex laws. But we do not expect our present laws to remain forever; the exploration of new phenomena and the use of more accurate instruments will bring to light inaccuracies in our present formulations that will necessitate the invention of still more complex laws, and so on forever. Scientific procedure thus may be represented by a curve which approaches but never touches a line. The curve is developing science, the asymptotic reality.

If law is an approximation, what does it approximate, and why should that to which it is an approximation be itself beyond discovery? To this latter question there appear to be four available answers. First, true laws may be unattainable because true laws do not exist, in that natural law only imposes certain limits on phenomena, within which limits indeterminacy prevails. Thus we might think that a man must grow to a height of more than three feet but less than nine, but that within these limits any height is possible, and that similar limits and similar possibilities are discoverable in human behavior or in any other phenomenon. More typical of contemporary belief is the idea that law merely determines the probability of any event, but that the event is always free to occur or not to occur. To take one example among many, Gamow has calculated the chances that an automobile in a closed garage will, for no reason whatever, suddenly appear outside it.

Second, true laws may be unattainable because of necessary defects in our sensory equipment. This is clearly true of such questions as whether another universe in another space exists, not causally related to our universe. Much the same thing may be true of an expanding universe: objects beyond a certain critical distance are just as unknowable as though they were in a different universe. Similarly, it was formerly argued that we could never observe objects smaller than half the wavelength of visible light, but this limitation was transcended, first by the use of ultraviolet photography, then by the electron microscope. And if sensation must occur through physical action, and there is a least quantity of action, then there is, by Heisenberg's principle, a minimum level of knowable detail.

Third, true laws may be unattainable because of defects in our intelligence. This view is best known to us in religion, where it has been maintained that certain things are rational and understandable to God, but mysterious and inscrutable to our limited understanding. But the view may also occur as part of a philosophy of nature: it may be argued that our minds have evolved for practical purposes, and that what was a satisfactory implement for enabling our ancestors to procure their food and avoid their enemies may be wholly inadequate for solving the problems of the universe. Nature, as well as God, may be regarded as inscrutable.

And, fourth, true laws may be unattainable because of fundamental limitations of the knowing process. We have already discussed the belief that certain perceptions, such as color, are in no way similar to the objective reality, and we have seen that analysis of this belief may reasonably lead to the conclusion that all knowledge is thus divorced from reality. This is the view of Kant and was recently presented in the following analogy. Suppose we are born in a windowless railroad control room and spend our whole lives there. In this room there are lights that show when a given section of track is occupied by a train, other lights that are repeaters, showing how track signals are set, and still others that show the position of switches. There may be many other devices as well, including levers or buttons that control switches and signals. In such a situation we will soon learn to expect certain normal sequences of light changes, and will learn what the various levers and buttons do to the lights; with the passage of time our ability to predict and our ability to control will progressively increase. Yet it would never occur to us to suspect the existence of track, trains, passengers, and freight, and in consequence we would never reach a completely adequate understanding of the system, or a flawless method of prediction and control.

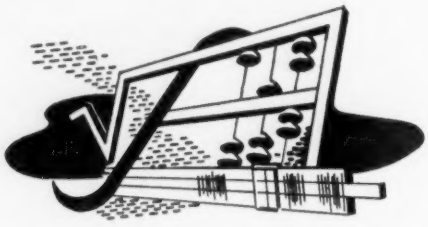
A further question is the nature of the reality to which our laws are approximations: a question intimately related to the last one we considered, but significantly different from it. First of all, it may be that reality is objectively present, more or less as we conceive it to be, but that there are certain necessary reasons why we can never know it. Thus it is perfectly compatible with relativity theory to assume that there is an objective or preferred coordinate system for the universe, as long as we are willing to admit that there is no way for human beings to find it—although no physicist, as far as I know, makes such an assumption. On the other hand, Heisenberg at one time made the equivalent assumption for his uncertainty prin-

ciple, believing that the orbital electron of a hydrogen atom has a precise position at a precise time, even though it is eternally impossible to verify such a location. Eddington, it may be remarked in passing, made a contrary interpretation popular. Similarly, it may be shown that it is impossible for a man to know, absolutely, a future event which it is within his power to alter, although a future event may be perfectly determinable to an outside observer. And other circumstances may be conceived that would render an absolutely objective and conceivable entity unknowable to us. On the other hand, reality may be so unlike our picture of things that to say that the picture is true of the reality is completely meaningless. Then I have no more right to say that this book is rectangular or thick, or weighs a pound, than we ordinarily believe we have a right to say it is red. Its redness is merely a predictive statement relative to an organism such as my own: if it is observed by an individual having eyes and nervous structure rather like mine, in conditions rather like those under which I see it, such an individual will get sensations of redness, and likewise of heaviness, and so on. Thus all that is meant by any statement about the world is a set of directions leading to a set of sensations. If this pragmatic view is adopted, as it is by many American physicists today, then a statement about the unknowable is completely meaningless. We are told by such persons to work only with what can be checked, and that two contradictory statements—such as the unresolved wave and corpuscular theories of light as they were understood half a century ago—could be equally true provided they did not predict different results for the same set of operations. According to this view, physical models are mere crutches to the understanding, and misleading crutches at that, which we would be better off without. I remember the case of an excellent student, who always tried to find out why certain physical laws or mathematical procedures were applicable: a colleague of mine regarded him with disapproval, feeling that one with such an inquiring mind would never make a physicist.

Finally, as a compromise between these two views, we have some who feel that, although nature has none of the qualities we perceive, nevertheless it is possible for the human mind to conceive if not to perceive it, and this by a continuous process of abstraction. Nature actually is the end product of abstraction: mathematics. And the universe is to be conceived of as a set of equations. The idealistic trend of this belief is obvious, and it is most easily conceived by us in relation to God, who becomes, in this view, the Great Mathematician postulated by Jeans.

Choice of Alternatives Difficult

It would be pleasant to close with a statement of my own choice of the alternatives available, but it is surely apparent that the problem is too great for such a treatment. The greatness of the philosophical difficulties need not, however, obscure an answer that we may give as scientists. For the scientist, as such, does not need to solve the philosophic problem except insofar as it affects his procedure. It is clear that the true law of nature, if there is such, is more apt to be found by an investigator who believes that there is one, than by an investigator who does not; that a good model of the atom is more likely to be found by someone who believes in models; and that a simplification of scientific laws is more apt to be achieved by a man who believes that nature is fundamentally simple. Thus, merely as a working hypothesis, the scientist should be committed to the optimistic views rather than to the current pragmatic or positivistic tendencies. I am speaking, of course, of the scientist *qua* scientist: insofar as he wishes to speculate philosophically he is entitled to do so, but he should not confuse philosophical speculations with his scientific hypotheses, and still less with his scientific results.



Food Production and Administration in Taiwan*

T. H. SHEN

A native of Chekiang Province, Dr. Shen received his graduate training at the University of Georgia and at Cornell. Upon his return to China in 1927 he taught plant breeding at Nanking University for ten years before he entered government service, first as chief technician, then as deputy director of the National Agritural Research Bureau. Dr. Shen became a member of the Sino-American Joint Commission on Rural Construction when it was organized in 1948 and is now with the commission in Taiwan.

TAIWAN is a treasure island. It has a surplus of food and other agricultural products such as sugar, rice, tea, bananas, pineapples, oranges, and camphor for export. About 92 per cent of exports in 1950 were agricultural products. The principal commodities imported are cotton, cloth, chemical fertilizers, soybeans, mechanical equipment, and petroleum. During peacetime, it had a favorable balance in foreign trade.

Now the island is under war conditions and has to maintain a big military force and support an increasing population. Its trade with Communist China on the mainland is blocked; consequently, it is confronted with an increased home consumption, expansion of the government budget, and a decrease in export trade. This paper will present food production and administration under such critical conditions.

The total value of agricultural production in 1948 amounted to $339,851,036 (equivalent to New Taiwan $1,699,255,179), approximately the same as that of industrial production.[1] Processed agricultural products, such as sugar and tea, constituted 80 per cent of the industrial production. The value of rice in 1949 was 36.84 per cent of the total value of agricultural products, sugar cane 16.19 per cent, and livestock products 20.16 per cent.

Taiwan has 876,864 hectares of cultivated land (24.38 per cent of the total land area, of which 528,097 hectares are paddy fields and 348,767 dry land.[2] The principal portion of the farming land lies in the western part of the island, because the mountains run from north to south and large plains lie in the west. There are 620,875 farm households and an agricultural population of 3,879,581, constituting 52.45 per cent of the total population. The acreage per household is 1.41 hectares, and that per person 0.23.

* Photos Courtesy ECA.

Natural Conditions

The principal characteristics of the climate of Taiwan are high temperatures, heavy rainfall, and frequent winds. Summer is long and hot, and winter is very short and mild. Even in the coldest month, although the peaks of high mountains are capped with snow, frost is rare on the plain. Throughout the island, the annual mean temperature is 21°–23° C. The mean monthly temperature rises from 20° C in April to 26°–28° C during June to September. The variation of winter temperature between the south and north is greater. The mean temperature of February at Hengchun, a town in the south, is 20.5° C and that at Taipeh is 14.8° C, a difference of 5.7°. This is an important reason why sugar cane, and bananas, pineapples, and other tropical fruits, are grown mainly in the southern and central parts of Taiwan but not in Taipeh District (or Hsien as administrative unit).

Taiwan has two rainy seasons, each differing in period and region. During the winter period, the strong northeast monsoon blows steadily, and the moisture-laden air condenses into clouds and rain that last from December to March in the north. During the summer the southwest monsoon prevails in the south, and frequent thunderstorms occur, giving abundant rainfall in the southern district. The average annual rainfall is 2582 mm, with more rain in June, July, and August (Table 1). The concentration of rain in summer is more significant toward the south, and the greater part of southern Taiwan receives more than 80 per cent of the annual rainfall from April to September. It is to these climatic factors that Taiwan owes its evergreen character and the success of its agriculture.

Taiwan lies in the course of the great cyclonic tropical storms known as typhoons, the most destructive of the natural calamities that occur in

The beautiful terraced hills of Formosa.

this agricultural island. A severe typhoon, bringing violent winds, heavy rainfall, and high tides, often does great damage to the land and to the field crops. According to the record, its occurrence is frequent during July to September and occurred 20, 28, and 23 times in July, August, and September, respectively, of the past 52 years.[3] The strong northeastern wind blowing along the coast from late October to late March also does damage to crops. Windbreak trees and shrubs have been planted for protection. Rice under protection of such windbreaks yields about 30 per cent more than without it.

The soils of Taiwan are classified into three large groups; i.e., zonal, intrazonal, and azonal soils.[4] The zonal soils are mature soils developed under the influence of the climate. These soils, such as mountain stony soils, podzols, gray-brown podzolic soils, yellow earths, and red earths, are all distributed in the mountainous and hilly regions of little agricultural importance, except the red earths existing on the tableland in Hsinchu and Taichung, which is one of the important areas for growing rice, tea, and citrus fruits. This soil is red in color, acidic in reaction, and poor in fertility and needs an adequate application of chemical fertilizers to increase the crop yield. In the hilly region of the central and southern part of the island, about 300–800 meters above sea level, bananas, pineapples, tea, and citrus fruits are often grown on red or yellow earths. These soils are also acidic and deficient in mineral nutrients (Fig. 1).

Intrazonal soils are developed under the influence of local conditions rather than climate. The main intrazonal soils in Taiwan are saline, and they exist along the coasts of Taichung, Tainan, and Kaohsiung. These soils are formed through the action of salts in the sea water. If the soil has a high content of salt, it is used as salt garden for making salt. Most of the saline soils which are al-

ready degraded are used for planting rice or for fish culture.

Azonal soils are immature soils—new deposits of various parent materials—and in Taiwan are classified into the following three groups: marine-deposited or planosol-like soils, sandstone and shale alluvial soils, slate and schist alluvial soils. The marine-deposited soils exist in Tainan and Kaohsiung. They are heavy-textured and slightly acidic to alkaline in reaction. This type of soil is mainly utilized for growing sugar cane. If irrigation is available, rice can also be grown. The slate alluvial soils are distributed between the rivers Dah-du and Si-lo in Taichung, on the eastern side of the river Hsia-tan-chi in Kaohsiung, and in the alluvial fan of Ilan and Taitung. These soils are characterized by dark color, high calcium content, and neutral reaction. This type is the most fertile soil on the island. Tobacco and rice are the dominant crops in these areas. The sandstone and shale alluvial soils occupy the major part of the cultivated area and are distributed from north to south. In the north the alluvial soils are acidic in reaction, whereas those in the south are slightly acidic to neutral or slightly alkaline. The main crops are rice and sugar cane. The schist alluvial soil exists in the eastern part of the island. It is high in lime content and alkaline in reaction. Rice, sugar cane, and peanuts are the dominant crops.

Because of the easy leaching of plant nutrients from the soil and heavy cropping the year around, the soils of Taiwan need heavy fertilization, which is accomplished by application of chemical fertilizers, growing of green manure crops, and turning under of compost.

FIGURE 1.

Cropping Systems

Cropping systems have been developed to meet local conditions such as distribution of rainfall and availability of irrigation and of chemical fertilizers. In the nonirrigated area of the southern part of the island, one crop of rice is grown from June to early December. In the northern part, there is no dry season, but the winter temperature is too low for good growth of rice, and there also one crop of rice is grown.

Up to June 1951 Taiwan had 530,000 hectares

TABLE 1
MONTHLY AVERAGE PRECIPITATION*
(In Millimeters)

	Taipeh	Hsinchu	Taichung	Tainan	Chiayi	Kaohsiung	Hwalien	Taitung
January	89	68	33	19	25	12	63	37
February	140	132	68	36	41	23	86	44
March	183	183	114	52	80	36	111	64
April	169	180	130	68	91	59	115	71
May	227	219	228	176	195	221	199	170
June	304	251	371	376	379	346	177	198
July	228	149	295	423	434	392	263	349
August	300	186	338	441	457	446	220	300
September	225	105	139	163	242	154	269	289
October	113	36	22	35	32	36	247	174
November	60	31	16	16	16	16	108	61
December	73	42	28	17	25	10	70	36
Totals	2111	1582	1783	1820	1999	1713	1927	1793

* C. H. Chen—*Taiwan Land Utilization*. Taiwan University, 17 (1950).

Plowing rice field.

under irrigation, about 60.44 per cent of the total cultivated land. In the irrigated districts (Fig. 2), two crops of rice are the main production. In the central and southern parts of the island, where irrigation has been well developed and where it is the center of rice and sugar-cane production, two-crop systems are generally practiced, as follows:[5]

1. The first crop of rice is transplanted from late February to early March and harvested in June; a summer catch crop is largely for green manure, being planted (usually interplanted) from late May to early June and plowed under in late July to August before transplanting the second crop of rice. The second crop of rice is transplanted from early August to early September and harvested from the middle of October to late November; the winter crop is largely for green manure, but in some districts it is sweet potatoes, flax, corn, wheat, tobacco, or vegetables.

2. Rice–sugar-cane rotation is commonly practiced in the Chia-nan Canal irrigation district in Tainan because there is not enough water to irrigate the 150,000 hectares. Three-year rotation is followed so as to have rice, sugar cane, and sweet potatoes (or other crops) grown every year in each 50,000 hectares. Rice gets irrigation from May to October north of the Pei-kang River and from June to September south of the river, sugar cane from September to January north of the river, and from November to April south of the river, and sweet potato or other crops none. Actually the whole area is divided into 1000 units, of about 150 hectares each. Rice, sugar cane, and sweet potatoes (or other crops) each occupy 50 hectares of each unit every year. The rice north of the Pei-kang river is grown from May to October, followed by sweet potatoes, peanuts, or other crops growing from October of the first year to September of the second year. Sugar cane is planted from September to November of the second year and harvested from November of the third year to March of the fourth year. A catch crop is interplanted in sugar-cane fields in November of the third year and plowed under in April of the fourth year as green manure for rice. The same rotation system is followed south of the Pei-kang River, but the growing period of the rice is about one month later.

In the irrigated districts of the northern part of the island, where the first crop of rice is harvested in July, the interim period before transplanting the second crop of rice in early August is so short that no summer catch crop is grown. The winter period from the harvest of the second rice crop to planting the first rice crop in the following year is long, and the winter crop grown is largely for green manure.

About 70 per cent of the first crop acreage is in northern Taiwan—Taipeh, Hsinchu, and Taichung districts—because of the high precipitation

Formosan farmer thins rice shoots.

during the winter in Taipeh and Hsinchu and the better development of irrigation in Taichung. Only in the irrigated area of the other districts is the first rice crop grown. With the high precipitation in summer, the second crop acreage is about 25 per cent more than the first rice crop.

Varieties of crops in such cropping systems are early in maturity. Of rice there are two groups: *japonica* and *indica*. The native varieties belong to *indica*. *Japonica* varieties have been introduced and developed by Japanese largely for export to Japan. When a sufficient amount of chemical fertilizer is applied, they mature earlier, lodge less, and yield higher than the *indica* varieties. During the Japanese occupation the acreage of *japonica* in the first rice crop was 69 per cent of the total in 1944 and in the second rice crop was slightly over 50 per cent. Since 1946, because of lack of export to Japan and an insufficiency of chemical fertilizers, their acreage is about 1 per cent less than *indica*. The native varieties yield better than *japonica* when chemical fertilizers are insufficient.

Production, Consumption, and Export

During the Japanese regime, Taiwan's food production had a great deal to do with its export to Japan. In the period of 1900–31 the Japanese laid emphasis on production of rice for export to Japan, by improvement and extension of irrigation and drainage, control of floods, adequate supply of chemical fertilizers, improvement of varieties and cultural methods, establishment of transportation, warehouse, and milling facilities, and development of credit systems. Production steadily increased during this period.

The total production of rice in 1930 was 343 per cent of that of 1900, as shown in Table 2, the acreage 189 per cent, and the yield per hectare 182 per cent. In 1930–40 the trend of rice increase showed little progress, though the highest production on record during Japanese occupation reached 457 per cent and the harvest yield per hectare 238 per cent in 1938, compared with 1900 base.

Sweet potatoes as supplementary food have been important only next to rice. The Japanese improved and encouraged the production in more or less the same way as rice. The trend of sweet potato production in 1900–50, as shown in Table 3, was somewhat similar to rice. The total production in 1930 was 645.59 per cent of that in 1900, the yield per hectare 205.54 per cent, and the acreage 314.08 per cent. In 1930–40 the trend of increase showed slow progress, although the production and acreage in 1937 were the highest on record during Japanese times. In the period of 1900–40 the percentage of increase in both production and acreage of sweet potatoes was significantly greater than rice because the crop is grown on dry

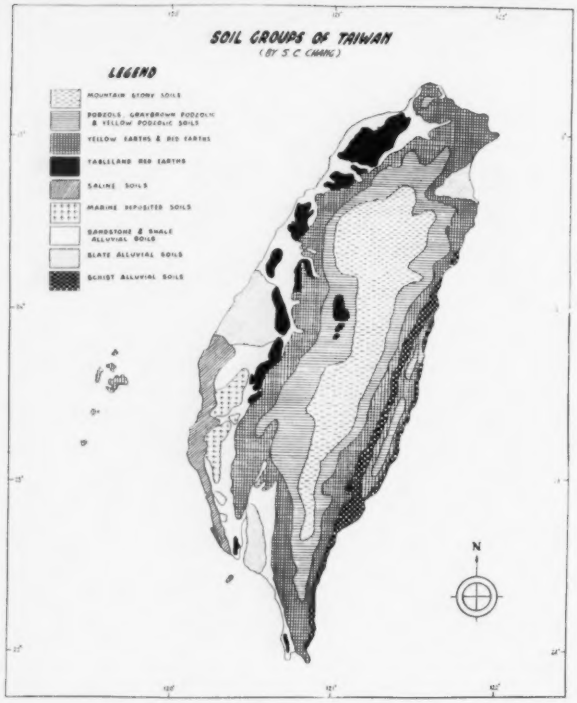


FIGURE 2.

land and stands adverse conditions better than rice. The possibility of improving sweet potatoes through breeding seems also greater than for rice. The big increase of sweet potato production and acreage in 1949 and 1950 further proves this point. It produces more food per acre than rice; hence, it should be considered a very important crop in food-deficit countries where natural conditions favor its growth.

Although the average rice production during the last decade of Japanese occupation had increased to about 350 per cent of that of 1900, the annual consumption per capita had decreased since 1925, as shown in Table 4. It reached 158.15 kg in 1925 and then began the trend of decrease. According to the world food survey made by the Food and Agriculture Organization of the United Nations, the average daily consumption per capita of Taiwan in 1934–38 amounted to 2153 calories and 52.2 grams protein.[6] The purpose of increasing rice production in Taiwan during Japanese occupation was largely for export to Japan, and as the population increased 63.75 per cent from 1925 to 1944, the people had to consume less rice and more sweet potatoes.

In the initial period of 1900–23 the net export of rice was usually below 170,000 metric tons.[7] In 1924–31 it ranged from 240,000 to 380,000 metric tons. In 1932–40 it varied from 409,631 (in 1940) to 720,410 metric tons (in 1934), the highest on record.

Since 1932, as rice production in Japan proper and the importation of rice from Korea have been increased, Japan did not need large amounts of rice from Taiwan; otherwise its own production of rice would be adversely affected because the cost of production in Taiwan was lower than in Japan. Then the Japanese emphasized sugar-cane production by maintaining rice acreage and increasing cane. The production of sugar in 1938–39 was 1,400,000 metric tons from 167,000 hectares—highest on record. The principal market for sugar was Japan, because the cost of production in Taiwan was higher than in Java, thus virtually excluding Taiwan from the world's markets.

World War II caused deterioration of food production to a large extent. To supply rice to the army and the Japanese people, Japan again encouraged rice production and also controlled the consumption of the Taiwanese. The food control was intensified after 1941, when Japan itself faced a great shortage of food. The government adopted food rationing and compulsory selling of rice by the farmers. The government controlled rice production, storage, milling, transportation, distribution, and selling. The farmers could save rice only for seed and their own ration and were required to turn the rest over to the farmers' associations, which were controlled by the government for mill-

TABLE 2

RICE PRODUCTION IN 1900–50*

YEAR	ACREAGE		YIELD OF BROWN RICE PER HECTARE		TOTAL PRODUCTION OF BROWN RICE	
	Hectares	Percentage	Kg	Percentage	Metric Tons	Percentage
1900	325,653	100	943	100	307,147	100
1910	456,276	140	1311	139	598,211	195
1920	500,169	154	1383	147	691,764	225
1930	614,390	189	1714	182	1,052,931	343
1938	625,398	192	2242	238	1,402,414	457
1940	638,622	196	1768	187	1,128,784	368
1950	770,262	236	1834	194	1,421,486	460

* Based on *Taiwan Food Statistics*. Food Bureau of Taiwan Provincial Government (1949).

TABLE 3

SWEET POTATO PRODUCTION IN 1900–50*

YEAR	ACREAGE		YIELD PER HECTARE		TOTAL PRODUCTION	
	Hectares	Percentage	Kg	Percentage	Metric Tons	Percentage
1900	39,855	100	5,168.6	100	205,996.4	100
1910	102,203	256.4	6,284.9	121.6	642,332.3	311.8
1920	112,825	283.1	7,417.3	143.5	836,852.0	406.2
1930	125,180	314.1	10,623.9	205.5	1,329,902.3	645.6
1937	138,997	348.8	12,734.0	246.4	1,769,984.9	859.2
1940	132,472	332.4	11,416.9	220.9	1,512,402.4	734.2
1949	236,164	592.6	9,172.0	177.5	2,166,048.0	1,051.5
1950†	235,000	589.6	9,442.0	182.7	2,209,000.0	1,072.4

* Compiled from *Taiwan Food Statistics*. Food Bureau of Taiwan Provincial Government, 53 (1948).
† The production and acreage in 1950 are only estimated.

ing, and to sell it to the government at the official price. A part of the polished rice was allocated for the civil ration at 10.54 kg per month per capita (or 143.44 kg brown rice per annum per capita), plus sweet potatoes as a supplement and also for the army at higher ration. The actual distribution of rice for civil consumption was less than this amount. The government exported all the rest to Japan. Due to the compulsory selling of rice at an official price, the farmers could hardly make a living and became reluctant to increase production. The condition became further deteriorated by a shortage of labor caused by the army draft and also a shortage of chemical fertilizers from the manufacturing plants in Japan, which were heavily bombed. Production decreased to 603,693 metric tons of brown rice in 1945, which failed to meet the people's minimum requirement of 857,000 tons. Rice export to Japan also steadily decreased from 270,824 metric tons in 1942 to 165,647 in 1944.

In the fall of 1945 the Chinese National Government took over Taiwan, abolished food control, and gradually rehabilitated agriculture in order in increase production. The production of rice, sugar, and sweet potatoes increased steadily from 1946 to 1948, but was seriously limited by a shortage of chemical fertilizers. The amount of brown rice produced was 842,848 metric tons in 1946 and 1,009,657 metric tons in 1948.

TABLE 4

RICE CONSUMPTION IN TAIWAN 1925–44*

YEAR	ANNUAL CONSUMPTION OF BROWN RICE		POPULATION
	Total (In M. T.)	Per Capita (In Kg)	
1925	631,343	158.15	3,992,000
1930	683,886	151.77	4,506,000
1935	576,004	111.95	5,144,000
1940	719,153	123.97	5,856,000
1944	904,996	138.47	6,536,904

* Compiled from *Taiwan Food Statistics*. Food Bureau of Taiwan Provincial Government, 52 (1948).

Since the Chinese National Government and Army moved to Taiwan in 1949, the population, according to the Statistics Office of the Provincial Government, increased from 6,807,601 in 1948 to 7,555,588 (7,029,459 Taiwanese and 524,940 mainland Chinese†) in December 1950, excluding about 600,000 military personnel. The government has made great efforts to increase the production of food for home consumption. Because of a shortage of foreign exchange only a limited amount of imported chemical fertilizers was available for rice and sugar cane. As a result of government efforts—and good weather—the 1950 production of both rice and sweet potatoes exceeded the record of Japanese times (Tables 2, 3, and 5), whereas the production of sugar, fruits, and tea was less than that of Japanese times. Based on the annual consumption per capita of 143.44 kg of brown rice, the civil consumption in July 1950–June 1951 amounted to 1,112,734 metric tons of brown rice and the military 200,180, and only about 76,942 metric tons of brown rice at the value of $10,321,912 was exported in the same period. About 11 per cent of the sweet potatoes produced have been consumed for food, 85 per cent for feeding hogs and cattle, and 3 per cent for manufacturing alcohol, because the import of soybean cake for feed from Manchuria has been greatly reduced and the use of potatoes for feed has increased.

The present status of agricultural exports is shown in Table 6. The export of rice is now only 10–20 per cent of that during Japanese times. The export of sugar, tea, and fruits has also decreased, mainly because the rehabilitation of production has not proceeded as rapidly as it might have. Consequently the government is facing a shortage of foreign exchange and is endeavoring to increase exports to other countries, chiefly Japan and the United States.

† According to another reliable source, the population of mainland Chinese was only half this figure.

Food Production Program

In cooperation with the China Mission of the Economic Cooperation Administration and the Joint Commission on Rural Reconstruction, the Provincial Government is carrying out (through the Food Bureau and the Department of Agriculture and Forestry) a food program by increasing the farmers' incentive for production, improving production facilities, and stabilizing food supply.

Of the farm population 35 per cent are owner-farmers, 27 per cent are part owner-farmers—farmers whose cultivated land is partly their own and partly rented from others—and 39 per cent are tenants. About 56.33 per cent of farmland is under tenant operation. The average farm holding for each tenant farm family is about 1 hectare. Before rent reduction, the average farm rent amounted to 50 per cent of the annual major crop yield (i.e., the major crop is rice, and the minor crops grown after harvest of rice belong entirely to the tenant). Hence tenant farmers were in a state of extreme poverty.

To improve the economic condition of tenant farmers and to increase their incentive for production, Ex-Governor Chen Cheng enforced the national Land Law in March 1949 by initiating the rent reduction program, under which the maximum farm rental must not exceed 37.5 per cent of the annual major crop and the lease tenure must be not less than six years. An ordinary tenant tills about 1 hectare of medium-grade paddy field and can harvest two crops of rice a year in the irrigated area, which amount to about 6000 kg of paddy rice. Before rent reduction, the tenant had to pay an annual rent of about 3000 kg of paddy rice to his landlord. Since rent reduction, he needs to pay only 2250 kg, which represents a reduction of 750 kg. To a poor tenant farmer, the 750 kg of paddy rice means enough increased income to eat and to live better—to the extent that the increase in production is not offset by the lower purchasing power of farm produce. Formerly, tenant farmers often did not have enough to eat and had to borrow food from their landlords; many now encounter no food shortage, and some of them are even able to sell their food surplus to procure other necessities. They are working harder to increase rice production because of a greater share accruing to them. This is one of the important factors in the big increase of rice production in 1949–51. Rent reduction has also helped the stabilize the social order of the rural community and to strengthen resistance against the threat of Communism. Even the Chinese Communists on the mainland had to admit these effects.

Rent reduction has also resulted in a steady decline in the price of tenant land—ranging from not less than one third to as high as 50 per cent in 1951 in comparison with 1948, the year before rent reduction. The landlords' interest in making investments in land is weakened and their desire to sell it is strengthened. This circumstance is favorable for inauguration of the second phase of land reform—a tenant land-purchase program. The government started the tenant land-purchase program with a public land-sale project, which it put into action in July 1951. The total acreage for sale

TABLE 5

ANNUAL PRODUCTION OF THE IMPORTANT CROPS IN TAIWAN*
(In 1000 Metric Tons)

	1937–39 (Av.)	1948	1949	1950	1951
Brown rice	1,374.8	1,068.0	1,214.5	1,421.5	1,510.7
Sweet potatoes	1,592.0	2,003.0	2,166.0	2,209.0	2,000.0
Wheat	3.2	6.5	10.1	21.3	20.0
Sugar	1,181.0	634.5	612.3	345.8	550.0
Peanuts	29.1	53.3	53.3	60.8	60.8
Soybeans	4.2	12.4	12.1	—	—
Tea	13.3	8.5	10.2	8.0	10.0
Bananas	200.7	110.4	98.4	120.0	125.0
Pineapples	185.0	20.1	17.7	26.0	40.0
Citrus fruits	33.7	28.4	26.8	25.0	30.0
Jute fiber	10.2	10.0	8.8	7.0	10.0
Ramie	0.98	0.76	0.9	0.8	0.7
Cotton	0.7	0.26	0.2	—	—
Tobacco	3.2	3.9	8.0	6.0	7.8
Vegetables	412.0	487.1	540.0	—	—
Green manure	2,031.0	1,929.6	2,675.0	—	—

* The data of 1948 and 1949 were based on *Taiwan Agricultural Yearbook, 1950*, and those of 1950 and 1951 were estimates made by the Agricultural Improvement Division of JCRR, with the exception of sugar (based on data supplied by Taiwan Sugar Corporation) and tobacco (based on data supplied by the Provincial Monopoly Bureau).

TABLE 6

ANNUAL EXPORT OF THE IMPORTANT AGRICULTURAL COMMODITIES
(In 1000 Metric Tons)

	1937–39 (Av.)	1948	1949	1950
Brown rice*	658.42	—	—	20.00
Sugar*	1,074.90	200.46	431.30	619.40
Tea	11.80	8.60	14.71	6.86
Bananas	142.55	25.49	12.62	11.60
Pineapples†	57.86	0.38	2.62	5.98
Citrus fruits	9.47	11.37	3.04	1.13

* The rice and sugar data were supplied by Keelung and Koahsiung Harbor Office, and the others by the Bureau of Inspection and Quarantine, the Provincial Department of Agriculture and Forestry. The rice export in 1950 included January-December 1950.

† The export of pineapple averaged in 1937–39 consisted of 2,699,777 kg fresh fruit and 1,213,535 cases canned fruit (equivalent to 55,160.6 metric tons). Each metric ton of fresh fruit makes 22 cases of canned fruit. The export included 59,916 kg of fresh fruits and 56,281 cases of canned fruit in 1949, and 20,027 kg of fresh fruits and 131,073 cases of canned fruit in 1950.

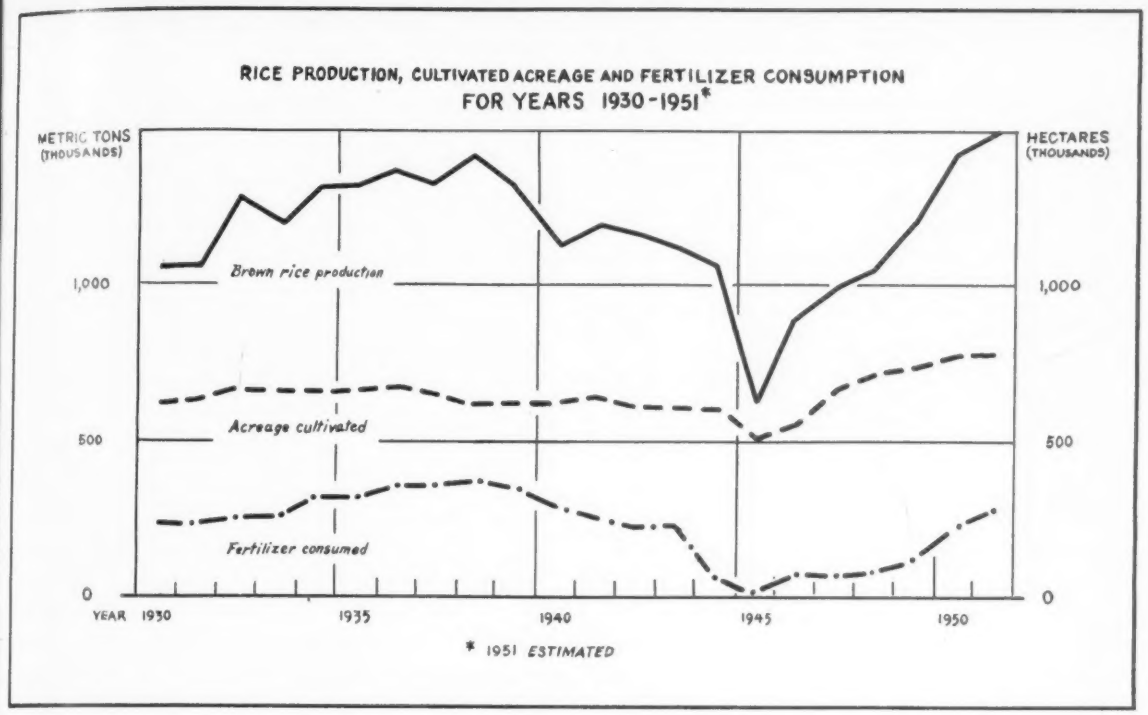


FIGURE 3.

at present is 86,000 hectares, 18.4 per cent of the total tenanted land. About 100,000 tenant families, 16 per cent of the total farm population, will be benefited under the project. This project will be completed this year, and then the government will require the private landlords to sell their surplus land to the tenant farmers. In fact, the government is already undertaking a landholding survey to provide the technical basis for implementing this program. Thus the whole process of present land reform in Taiwan consists of three steps: rent reduction, limitation of private landholdings, and land purchase by tenants. The Joint Commission on Rural Reconstruction has given to the Land Bureau of the Provincial Government financial and technical aid for the whole program of land reform.

Fertilizers and water are two major factors for higher production of crops on the island. The high correlation among rice production, the area devoted to rice, and the amount of chemical fertilizers applied in 1930–50 is shown in Figure 3. The provincial government and the ECA China Mission purchased 231,934 metric tons of chemical fertilizers for rice in 1950 and about 280,000 metric tons in 1951. The status of fertilizer distribution for different crops in 1950 is shown in Table 7. The total amount of fertilizer procured for different crops in 1951 was 372,877 metric tons. The projected allocation included more crops than in 1950 —namely, rice, sugar cane, sweet potatoes, wheat, jute, pineapples, tobacco, tea, citrus fruits, and citronella.

In addition to chemical fertilizers, the amount of compost manure has been increased by repairing farmers' compost houses and encouraging hog production. Up to June 1951, JCRR and the Provincial Department of Agriculture and Forestry had jointly helped 15,558 poor farmers repair their compost houses with a subsidy of about $15.00 (NT $150.00) to each farmer. The poor farmers repaired the compost houses with JCRR subsidy, but many well-to-do farmers were inspired to repair their compost houses with their own money. According to a survey by the Department of Agriculture and Forestry, there are about 360,000 compost houses on the island. One third are in good condition, but the rest need repair. Currently, Taiwan produces about 8,000,000 metric tons of compost, a considerable portion of which is produced outdoors. According to conservative estimate, the nutrient elements contained in 1000 metric tons of well-made compost are equivalent in amount to those contained in 10 metric tons of ammonium sulfate, 5 metric tons of calcium superphosphate, and 7 metric tons of potassium sulfate. Thus 8,000,000 metric tons of compost are therefore equivalent to about 80,000 metric tons of ammonium sulfate, 40,000 metric tons of calcium super-

phosphate, and 56,000 metric tons of potassium sulfate. If the 360,000 compost houses can all be repaired and fully utilized, each house can be expected to produce 40 metric tons of compost a year, and the total annual production will be 14,400,000 metric tons, equivalent to 144,000 metric tons of ammonium sulfate, 72,000 metric tons of calcium superphosphate, and 100,800 metric tons of potassium sulfate, in addition to the large amount of organic matter turned back to the soil.

JCRR, in cooperation with the Provincial Department of Agriculture and Forestry, is increasing production of green manure crops by multiplication and extension of their seed. JCRR is also demonstrating application of lime to the two kinds of acid soils, with favorable response in rice production, especially in red and yellow earths, the chemical reaction of which is around pH 4.5. The government has built six chemical fertilizer plants, with an annual production capacity of 7000 metric tons of ammonium sulfate, 66,000 metric tons of cyanamid, and 51,000 metric tons of calcium superphosphate and fused phosphate, and, with ECA aid is expanding the ammonium sulfate plants to a capacity of 33,000 metric tons. Thus in the future imported chemical fertilizers will furnish a substantial supplement to the locally supplied fertilizers.

The demand for water is so great that in spite of high annual precipitation it is necessary to supply water by irrigation during the period of deficiency of rainfall. Before the Japanese occupation in 1895 the Chinese who emigrated from the mainland had built dikes for flood control of some torrential rivers and had developed the irrigation of 196,679 hectares, 56 per cent of the total cultivated land of 351,019 hectares. In the period of Japanese occupation in 1895–45, the Japanese improved and extended the irrigation and drainage systems by the modern technique of hydraulic engineering. By 1945 the total irrigated area was 532,208 hectares (*Taiwan Agricultural Yearbook, 1950*), but the area actually irrigated was probably below 500,000 hectares, because many systems were in disorder in the latter part of World War II. The irrigation system consists of a network of canals and laterals that derive their water supply from natural streams. In many instances it is necessary to augment the natural flow of the stream by construction of storage reservoirs. Some use is also made of wells to supply irrigation demands.

Since the return of Taiwan to China irrigation

TABLE 7

STATUS OF FERTILIZER DISTRIBUTION IN 1950*
(Metric Tons)

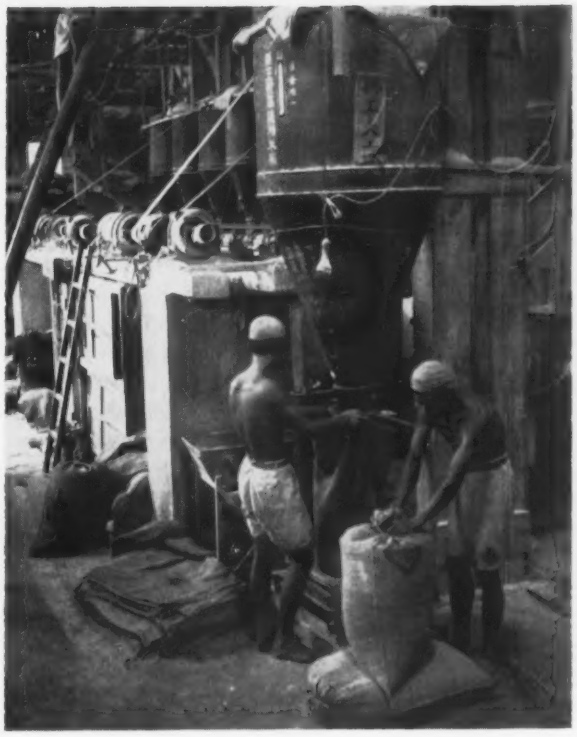
CROPS DISTRIBUTED FOR	FIRST RICE CROP	SECOND RICE CROP	SUGAR CANE	WHEAT	VEGETABLES	TOTALS
Government procurement						
Ammonium sulfate	19,073.13	48,826.59	23,000.00	1,430.70	9.18	92,339.60
Ammonium phosphate	1,208.61	—	—	6.60	—	1,215.21
Ammonium nitrate	51.65	247.27	—	1.87	—	300.79
Chile nitrate	250.51	2,791.08	—	54.20	—	3,095.79
Calcium superphosphate	10,744.61	15,631.90	15,000.00	28.75	4.59	41,409.85
Calcium cyanamid	—	1,886.92	12,000.00	—	—	13,886.92
Potassium chloride	—	—	5,000.00	—	—	5,000.00
ECA procurement						
Ammonium sulfate	41,238.83	59,403.89	—	136.10	101.00	100,879.82
Ammonium phosphate	12,167.58	9,692.54	—	—	—	21,860.12
Calcium ammonitrate	—	—	9,954.00	—	—	9,954.00
Ammonium superphosphate	—	8,711.48	—	1,516.99	—	10,288.47
Sweepings (A/S A/P)	—	7.56	—	—	—	7.56
TOTALS	84,734.92	147,199.23	64,954.00	3,175.21	114.77	300,178.13

* Compiled by the Food and Fertilizer Division, JCRR, from data supplied by the Provincial Food Bureau.

systems have been maintained, improved, or newly built in more or less the same way as in the Japanese period. Four unfinished projects started during the Japanese period, 12 large and 163 minor new projects have been taken up by the Provincial Water Conservancy Bureau in cooperation with the local hydraulic associations. When this program is completed, 72,843 hectares will have the benefit of new irrigation or drainage, and the systems for another 70,370 hectares will be improved. In cooperation with the Provincial Water Conservancy Bureau the JCRR has assisted, since the winter of 1949, 23 irrigation and drainage projects, of which most are projects under the bureau's program. In the summer of 1951 the acreage under irrigation had been increased to 530,000 hectares, about 60 per cent of the total cultivated land.

A system of pure seed multiplication and extension of the improved varieties of rice, sweet potatoes, wheat, bananas, pineapples, citrus, vegetables, tea, and jute has been established by JCRR in cooperation with the Provincial Department of Agriculture and Forestry and the farmers' associations. The system consists of three steps: foundation seed, stock seed, and extension seed. The foundation seed of an improved variety is multiplied by provincial experiment stations for planting stock seed. The stock seed is multiplied partly by provincial experiment stations and partly by contract with farmers for planting extension seed. The extension seed is multiplied by these farmers for sale to other farmers to replace their own degenerated seed. The increase of yield per hectare as a result of the renewal of seed has been conservatively estimated at 5 per cent in the case of rice. In addition to the seed inspection service, JCRR has subsidized the seedgrowers in building seed-drying grounds and seedbins to prevent mixture with seeds of other varieties grown on the same farm. Extension rice seed is annually available to renew farmers' seed sufficient for planting 200,000 hectares, about one third of the total rice area. In order to maintain the purity of a variety, farmers are advised to renew their rice seed every third crop (there being two crops annually). Thus for every third crop farmers throughout the island may obtain extension seed.

A pest control program for rice, vegetables, and fruits, in which pesticides such as DDT, derris extract, and new improved granosan are supplied to the farmers' associations, has reduced the pest damage to a large extent. The warehouse loss of rice in a period of four to five months, caused by insects such as grain weevils and moths, is averaged at 5 per cent, wheat 15 per cent, and sweet potato chips 30 per cent. A control measure is being developed by spraying the grain bins with DDT and mixing the grain and potato chips with Pyrenone powder. For the storage of big stocks of food, 158 warehouses of the farmers' associations have been repaired and 62 new ones have been constructed by JCRR and the Provincial Food Bureau. They have increased the storage capacity by 40,175 metric tons of rice, or 18.26 per cent of 220,000 metric tons, which is the total warehouse capacity of the farmers' associations (based on the 1949 survey).



Inside huge Farmers Association warehouse rice is bagged for shipment.

The population of hogs was 1,362,159 in 1949[8] and was estimated at about 1,500,000 in 1951. They not only supply meat but are a major source of manure for crops. In cooperation with the Provincial Department of Agriculture and Forestry and the farmers' associations, the JCRR has been carrying on continuous vaccination of hogs for more than a year, as protection against hog cholera and erysipelas. It is estimated that the veterinary service has reduced the number of deaths of hogs by half, or a saving of 1 per cent of the hog population. For improvement of quality, JCRR has imported 656 Berkshires from Japan and the USA for production of hybrid market pigs. A similar program is being conducted with cattle, water buffaloes, and poultry.

In order to check inflation, the government limits

the amount of credit loans to farmers, who have to borrow money at exorbitant rates of interest from usurers, thereby increasing the cost of crop production. The Provincial Food Bureau, through the Bank of Taiwan, extended to rice farmers a three months' credit loan of NT$30,000,000 (equivalent to about $2,000,000 U. S.) at harvesttime—June and July 1951—to be returned in rice; the rice price for repayment of the loan was fixed at NT$0.74/kg of paddy rice. Simultaneously, the bureau announced the minimum price of paddy rice as NT$70.00/100 kg, which was close to the prevailing market price at that time. The bureau will purchase rice at this price when the market price falls below this. This loan has not only met a part of the farmers' needs but, together with the support price, also stabilized the seasonal downward trend of the price of rice after harvest of the first 1951 crop. For example, the price of Ponlai brown rice in Taipeh was NT$64.64/60 kg (or NT$82.5/100 kg of paddy rice) during June 1–10, NT$59.33 July 1–10, NT$60.66 August 1–10, and NT$64.00 September 1–10. With the good result of the first rice loan the Food Bureau extended another loan of NT$30,000,000 to rice farmers for the second crop of rice.

The government also extended from the ECA counterpart fund to sugar-cane farmers a production credit loan of NT$77,000,000 (equivalent to about $5,000,000 U. S.) for 18 months from August 1951 (because sugar cane in Taiwan requires 18 months from planting to harvesting). A

Harvesting sugar cane.

few marketing credit loans for tea, tobacco, bananas, jute, and fisheries were extended by the government in 1951.

Government Collection and Disposition of Rice

The Food Bureau of the Provincial Government is the sole agency for collecting rice from farmers through the system of barter and credit loans, and from landowners through taxes in kind and compulsory purchases. The Food Bureau barters for rice chemical fertilizers which have been imported partly by ECA and partly by the government. By the application of 175 kg ammonium sulfate to a hectare, the paddy rice production is increased in about a 3:1 ratio; i.e., 1 kg ammonium sulfate produces 3 kg paddy rice. The barter ratio of ammonium sulfate with paddy rice is 1:1. Thus a rice farmer can get two thirds of the increased product after paying rice for the fertilizer. In accordance with this principle, the barter ratio of chemical fertilizers has been set up since 1950 by the Provincial Food Bureau as follows:

Fertilizers	Paddy Rice
Ammonium sulfate	1:1.0
" phosphate	1:1.3
Calcium superphosphate	1:0.4
Ammonium nitrate	1:1.4

In case a poor farmer has no rice to barter for fertilizer, he is permitted to get it on a loan basis and to return the rice after harvest.

Little cotton is produced in Taiwan. Cloth is expensive for the farmer because he sells his rice at a low price and buys cloth at a comparatively high price from a retailer. In 1950 the Food Bureau imported 2,063,051 yards of cloth from Japan and bartered it, at the request of farmers, for rice. The barter price of cloth was 80 per cent of the wholesale market price, and that of rice was the market retail price. Through this barter a farmer paid 30–40 per cent less money for his cloth. Each of 400,000 farm households in Taiwan purchased 5 yards of this cloth, or enough for two suits. This barter benefited the farmers and increased the government stock of rice. The Food Bureau imported 2,381,837 yards of cloth during January–August 1951 to barter for rice; it also imported soybean cakes to barter for rice in a similar way.

The Finance Department of the Provincial Government has levied three taxes on landowners: land tax, surtax, and defense tax. Following a system established during Japanese times, the land tax is based on 4 per cent per annum of land value; for illustration, a hectare of the first-grade rice land is levied at 49 Taiwan dollars. Since the land tax is collected only in rice, the rice tax Taiwan dollar remains fixed at 8.85 kg of paddy rice. Thirty per cent of the land tax collected is appropriated to the provincial treasury and 70 per cent to district and municipal (local) governments. The surtax amounts to 30 per cent of the land tax and is allocated entirely to the local governments for compulsory education in the primary schools. The defense tax is also equivalent to 30 per cent of the land tax (the public land is free from it) and has been established since 1950 because the island was in danger of the Chinese Communist attack and the military budget was greatly expanded. Half the defense tax is allocated to the district and municipal governments for defense works and another half to the provincial treasury for its contribution to national defense.

According to the tax record book prepared in the above way by the Finance Department, the Provincial Food Bureau collects land tax, surtax, and defense tax in rice. Besides, it makes simultaneously two kinds of compulsory purchases of rice from landowners. The first is the purchase of an amount of rice equivalent to the total of land tax and surtax a landowner pays. The second is confined to the landlord, who pays more than 1500 kg of rice in land tax, and applies on a progressive basis to so-called surplus rice. The "surplus rice" is calculated by subtracting the land, surtax, and defense taxes, the amount of the first kind of compulsory purchase, and 2520 kg of paddy rice for family consumption from the total land rent collected in kind by the landlord. A progressive rate of purchase is applied to this surplus rice: 40 per cent of the surplus rice from landowners paying above 1500 kg and below 5000 kg of rice in land tax; 45 per cent from those paying above 5000 kg and below 10,000 kg; 50 per cent from those paying above 10,000 kg and below 20,000 kg; 55 per cent from those paying above 20,000 kg and below 30,000 kg; 60 per cent from those paying above 30,000 kg. The Taiwan dollar rice price for the two kinds of compulsory purchase is fixed by the provincial government with approval of the Legislature. Often the compulsory purchases include a tax element, inasmuch as the purchase is below the market price. The fixed price was NT$0.70/kg of paddy rice for the first crop of rice in 1951, which was very close to the market price, and NT$0.80 for the second crop, which was about 10 per cent less than the market price. The Food Bureau also gets the repayment of its rice production loans in rice, and the rental in rice on public land from the farmers who rent it.

Through the barter system tax collection, compulsory purchase, credit loans, and rental on public

land, the government has been able to control 25–30 per cent of the annual rice production of the island, equaling about 375,000 metric tons of brown rice in 1950, and about 461,000 in 1951. The breakdown in percentage of the rice collection by the government in 1951 is as follows:

	Percentage
Barter of chemical fertilizers	51.22
Barter of cloth	4.51
Production loans repaid in kind	12.32
Land tax	9.45
Surtax	2.84
Defense tax	2.73
Purchase prorated to the total of land tax and surtax	12.81
Surplus rice purchase	2.44
Rental on public lands	1.68
	100.00

The government rice stock has been used largely for rationing to the military forces, the police, civil servants, and public school staffs, for an emergency reserve stock, for stabilizing the market price of rice, and for export.

Food Problems

Rice production, which was preliminarily estimated by the Food Bureau at 1,510,689 metric tons of brown rice for 1951, is still limited by the amount of chemical fertilizers imported. The rice production in 1950 was practically the same as that for 1938, but the acreage was 770,106 hectares in 1950 and 625,398 in 1938. The yield of brown rice per hectare was 1.83 metric tons in 1950 and 2.24 in 1938. This was largely due to difference in supply of chemical fertilizers for the rice crop (389,334 metric tons in 1938 and 235,000 in 1950) (Table 8). It is the same with sweet potatoes. The production and acreage of sweet potatoes in 1949 and 1950, as shown in Table 3, were the highest on record, but the yield per hectare was lower than 1930–40. This also was due to a shortage of chemical fertilizers. As increase of cultivated land is rather limited, the crop yield per hectare should be specially emphasized. New chemical fertilizer plants should be established to produce more fertilizers for home consumption.

Irrigation is also essential to increase production per hectare. Based on the reconnaissance survey, the Provincial Water Conservancy Bureau plans to increase irrigation by about 120,000 hectares (about 14 per cent of the present cultivated land). It should be pointed out that the maintenance and improvement of present irrigation systems are equally important as development of new irrigations.

To increase the cultivated area, the reclamation of coastal land has been successful, with the building of dikes and the draining of salt from the soil by stream water and the natural rainfall. As the seashore is still extending in some districts, reclamation is an economic means of increasing cultivated land. At the same time, deforestation on some hills has caused soil erosion, and hence soil conservation practices are also essential to maintain the good earth.

The farmers now are more concerned with economic problems. In order to check inflation, the government has stabilized the price of rice and other farm products and is attempting to regulate the price of imported goods by selling ECA commodities. In fact, the price disparity in favor of manufactured and imported goods has become a serious problem. The Rural Economics Division, JCRR, has compiled the parity price of rice since April 1950 by using September–December 1949 as a base period and taking 21 and 9 items of consumers' and producers' goods as a basis for calculation.‡

The percentage of the actual price of rice to its parity price was 80.37 in August 1950, 72.38 in December 1950, 84.82 in March 1951, 70.84 in May 1951, and 61.07 in July 1951. Farmers, as

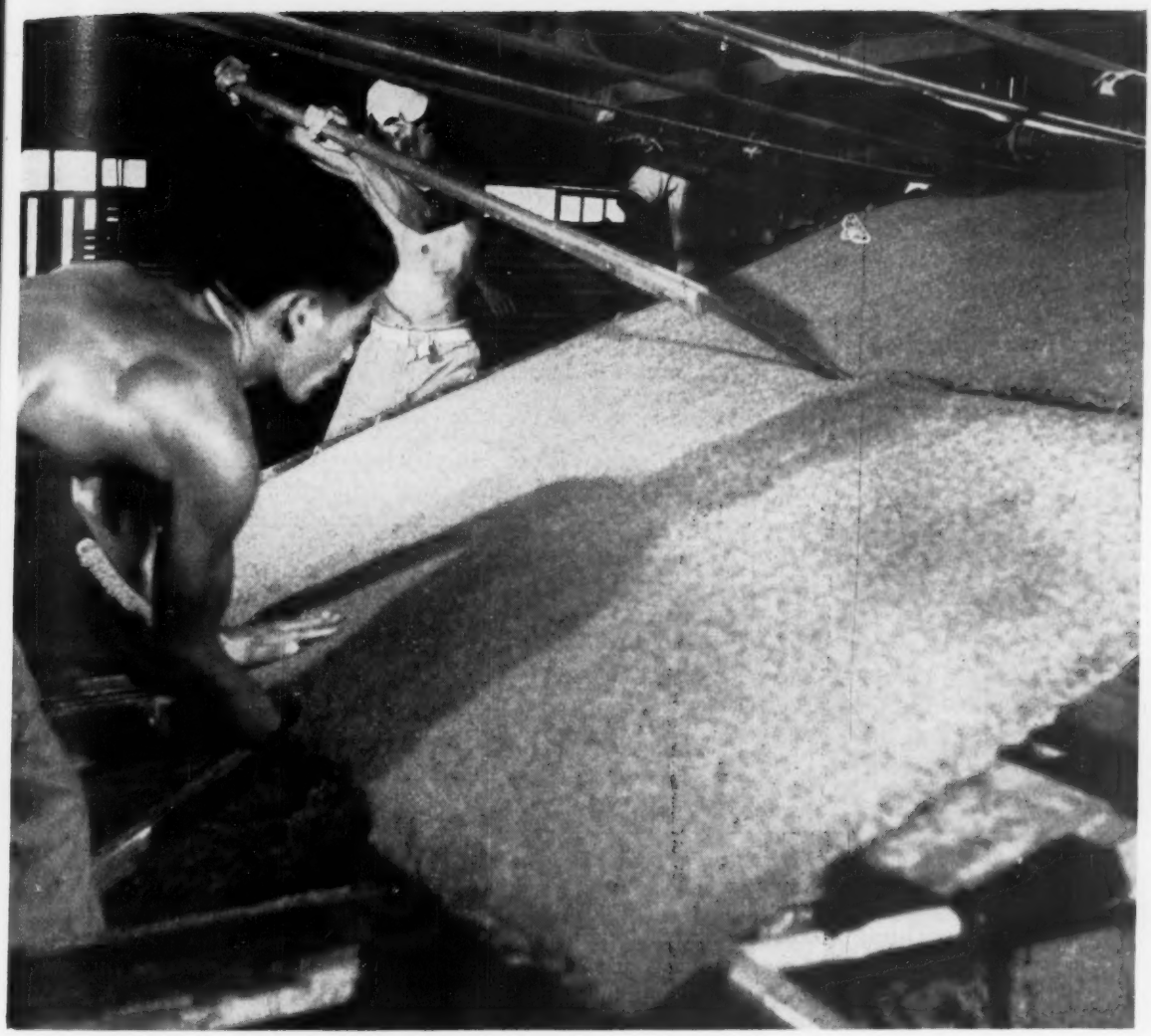
‡ The twenty-one items of consumers' goods include wheat flour, pork, beef, salt, soy sauce, white sugar, matches, firewood, dyed shirtings, grey nankeen, cement, rape seed oil, tea, cigarettes (Paradise), towels, soap, aspirin, wages for mason or carpenter, prepared tobacco, rubber shoes, and second-grade cotton; the nine items of producers' goods include bean cakes, ammonium sulfate, calcium superphosphate, wages of male and female labor, plows, barrows, derris powder (pesticide), and land tax.

TABLE 8

Relation of Chemical Fertilizers to Rice Production*

Year	Rice Acreage		Application of Chemical Fertilizers		Brown Rice Production	
	Hectares	Percentage	M. T.	Percentage	M. T.	Percentage
1938	625,398	100	389,334	100.0	1,402,414	100.0
1945	502,018	83	1,958	0.5	638,828	45.5
1949	747,675	119	116,691	29.9	1,214,523	87.6
1950	770,106	123	235,000	60.4	1,401,051	100.6

* R. C. Li. *Food Production in Taiwan*. Special publication of the newspaper *Sin-sun*, Taiwan (January 1, 1951).



In one of last stages of refining workers cut sheet of pressed sugar.

producers, receive low prices for their products and, as consumers, pay high prices for necessities. The benefits a farmer has received from the bartered fertilizers, rent reduction, and the good crop have been minimized by the disparity in prices. The people now eat more cheap rice and much less sweet potato than during the Japanese regime. As Japan and the Philippines do want to buy Taiwan rice at the world market price, which is about $50.00 per metric ton of brown rice higher than the local price in Taiwan at present (May 1951), about 150,000 metric tons of brown rice were expected to be exported in 1951–52. To stabilize the local price of rice and at the same time stimulate farmers' incentive to increase production, the realistic way seems to be to increase barter of exported rice with cloth, chemical fertilizers, and other necessities for distribution to farmers, as has been done by the Food Bureau. In other words, the farmers would share a certain portion of the export profit and the government could get a larger share to balance its budget. Thereby the farmers would eat more sweet potatoes in order to sell more rice for export.

The high interest rate from usurers has increased the cost of food production. Because of the tight financial situation the government banks can extend only a limited amount of production and marketing credit loans on short terms, and the amount is apparently not enough to meet the needs of the farmers.

Under present abnormal conditions, the government has to maintain a big armed force of 600,000 men and balance the budget through taxation, control of foreign exchange, and other means. However, as a result of the government effort and

American economic and military aid, the food and economic situation is better than it would be otherwise, but not as good as may be expected under normal conditions.

Can the food and other economic situation of this island be better in the future under peacetime conditions when only a small army need be maintained? Yes, if the present civil population of 7,029,459 Taiwanese (excluding mainland Chinese, because most of them will return to the mainland when the Communist trouble is over) could be stabilized. According to Table 4, the population had increased 63.75 per cent in the period 1925–44. Table 9 shows that except in 1947 and 1948, when

TABLE 9

ANNUAL RATES OF BIRTH, DEATH, AND POPULATION INCREASE PER 1000 IN TAIWAN*

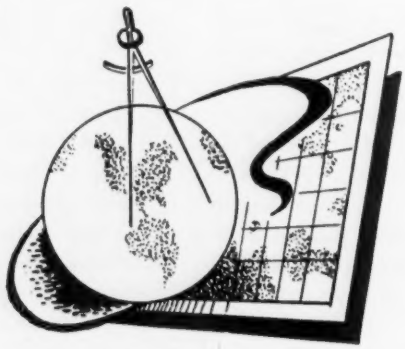
YEAR	BIRTH RATE	DEATH RATE	POPULATION INCREASE RATE
1912	42.52	25.75	16.77
1917	41.94	28.04	13.90
1922	42.76	25.58	17.18
1927	44.25	22.87	21.38
1932	45.02	21.03	23.99
1937	45.89	20.36	25.53
1942	41.21	18.37	22.84
1947	37.09	17.57	19.52
1948	38.75	14.00	24.75
1949	40.67	12.62	28.05
1950	43.50	11.35	32.15

* Based on *Health Statistics of Taiwan in 1948 and 1949*, p. 145. Provincial Health Bureau, Taiwan.

the birth rate due to the effect of the army draft during World War II dropped to 37.1 and 38.8 per thousand, the annual birth rates in the period 1912–50 varied from 40.7 to 45.9 per thousand. On the other hand, the annual death rates steadily decreased from 28.0 to 11.4 per thousand in the same period. Consequently, the annual rate of population increased from 13.9 to 32.2 per thousand. As health conditions are being improved, the death rate will further decrease, and the annual rate of population will naturally increase unless the birth rate can be checked. At an annual increase of 30 per thousand, the present population of Taiwanese would be doubled in twenty-five to thirty years. Then, even with the possible combination of the highest yield per hectare of rice and sweet potatoes as in 1938 and 1937, with the largest acreage, as in 1950, food would be barely enough for low consumption per capita of 14 million people, and the economic situation would become much worse. In conclusion, despite the better utilization of agricultural and other natural resources, the stabilization of population is essential for the future prosperity of this treasure island.

References

1. *Taiwan Agricultural Yearbook, 1950.* Taipeh: Provincial Government of Taiwan, Dept. Agr. and Forestry (1950).
2. *Ibid.*
3. CHEN, C. H. *Land Utilization in Taiwan.* Taipeh: Taiwan Univ., 17, 26 (1950).
4. HSI, L. T., and CHANG, S. K. *Report on Soil Survey and Fertility Tests in Taiwan.* Bull. No. 5. Taipeh: Taiwan Fertilizer Co., 17–58 (June 1951).
5. *Survey of Cropping Systems* (in Japanese). Taipeh: Government of Taiwan, Production Bureau, Fundamental Survey Bull. No. 35, 1–7 (March 1937).
6. SHEN, T. H. *Agricultural Resources of China* (App. Tables 4, 6). Ithaca, N. Y.: Cornell Univ. Press (1951).
7. YEH, S. M., and HSIEH, S. C. *A Report on the Rice Export in Taiwan.* JCRR, mimeo. (July 1951).
8. *Taiwan Agricultural Yearbook, 1950.* Taipeh: Provincial Government of Taiwan, Dept. Agr. and Forestry, 171 (1950).



Architecture of Herbaceous Plants

LORA MANGUM SHIELDS

Lora Mangum Shields' first teaching experience was in the public schools of New Mexico, her native state. She took her Ph.D. in botany at the University of Iowa in 1947 and since that time has been on the staff of the Department of Biology of New Mexico Highlands University. Upon the retirement of Fred W. Emerson a year ago she became head of the department.

PLANT structure, like nearly all properties of organic forms, is closely identified with the mode of life of the species and the specialized activities of individual parts. Ordinarily the internal construction of a plant organ is influenced by its function, external form, and orientation with respect to the main plant axis. The extent of development and the arrangement of internal reinforcing elements are usually related to the position and symmetry of the plant part and its surface : volume ratio. The organization of many plant structures suggests that in the operation of natural selection in the vegetable kingdom economy of construction material in the arrangement, balancing, and orientation of plant tissues and organs for effective functioning was an important survival factor.

Reinforcements in Plant Structures

The design of a bridge or a roof is satisfactory only if it insures maximum strength and solidity with a minimum expenditure of material. To this end supporting elements of the structure must be arranged according to approved mechanical principles. The same physical laws observed in the construction of a modern railway bridge governed with even greater perfection the development of plant skeletal systems in earlier geological periods. That nonwoody plant parts are provided the necessary support with a conservative expenditure of material is evidenced by the delicacy of such structures as most leaves and by the slight skeletal residue remaining after the average herbaceous plant withers.

Each plant structure develops the requisite mechanical strength. Organs are constructed to withstand in some cases a transverse or bending stress, in others a longitudinal pull, in still others longitudinal compressions, radial pressures, or shearing stresses. Since the distension of cells by an abundant supply of water, which lends rigidity to their enclosing cellulose walls, is frequently influenced by external conditions, more reliable mechanical arrangements provide the main support for most plant structures. Mature, longitudinally oriented water-conducting cells of the xylem insure some degree of inflexibility. Since each bundle of vascular tissue is composed in part of delicate food-conducting elements and young xylem cells, the development of a coarser, more resistant adjacent tissue is mechanically necessary. The specialized supporting elements of stems, leaves, and petioles include the hard-walled, nonliving sclerenchyma, which often forms a gutter-shaped sheath or splint girdling the vascular bundle, and flexible, living collenchyma which, like sclerenchyma of certain species, becomes oriented in peripheral strands or a solid sheath elongate in the same direction as the component cells. The qualitative and quantitative development of the mechanical system, in general hereditary characteristics of the species, is subject to a limited extent to environmental action, as in parts of young tree trunks which produce more wood when kept in motion by wind, or in leaves and stems which vascularize more heavily in a xeric habitat.

Various architectural schemes in plant parts are associated with different functions and orientation patterns. Every upright axial organ bearing the weight of branches and foliage requires the kind of rigidity characteristic of a column. Supporting strands in such aboveground parts ordinarily arrange themselves in one or more broken or irregular circles toward the periphery, forming a hollow cylinder composed of dense, heavy-walled cells, illustrated by the supporting framework of the herbaceous dicot stem (Fig. 1). The six or more

modifications of a cylindrical arrangement of the supporting tissue in herbaceous stems have in common a decidedly peripheral disposition of mechanical strands, affording protection against bending strains, supplying maximum rigidity with a minimum expenditure of material and the least possible exposure of transpiring surface.

Special stiffening arrangements are not essential in organs pervaded by wide air passages where these parts are buoyed up by water in an aquatic habitat, as in the case of *Myriophyllum* and *Elodea* stems (Figs. 2, 3), where the small amount of mechanical tissue forms a central core. Haulms of Juncaceae (Fig. 6) and Cyperaceae, on the other hand, are supported by a subepidermal circle of I-girders, frequently spaced at irregular intervals, and are often hollow.

In wind the mechanical strength of the entire root system is tested, different portions in turn being stretched taut, like cables in a storm. The degree of inextensibility of a structure depends upon the cross-sectional area of its resistant elements, provided the stretching force is uniformly distributed. The more closely the resistant elements are aggregated, the more uniform the distribution of tensions. For this reason the concentration of mechanical tissue in a single, compact, cablelike strand, as in monocotyledon and dicotyledon roots (Figs. 4, 7) is the most advantageous arrangement for subterranean organs that must withstand longitudinal tensions. At the point where the root joins the stem this concentration of vascular and supporting tissue divides into the individual bundles that become oriented in the characteristic pattern in the main axis aboveground. In many rhizomes which function in anchorage, particularly those of grasses and sedges, mechanical tissues are united to form a solid central strand (Fig. 5), more closely approximating root organization than that of the morphological equivalent of the rhizome, the stem.

A more or less flattened organ, such as the foliage leaf, is chiefly exposed to bending stresses in the plane perpendicular to its greatest surface. Each of the two lateral halves is frequently oriented at a vertical angle on either side of a large midvein, supported by a skeleton in the corresponding form of an inverted wedge (Figs. 10, 11), particularly efficient in relieving bending stresses. In accordance with the nature of the mechanical requirements of leaves, their main internal supporting elements are arranged at right angles to the surface and are roughly parallel. Such girders may be deeply internal or barely subepidermal, or both these types may appear in any particular leaf. In most grass and sedge leaves subepidermal I-girders, consisting of sclerenchyma and the enclosed vascular bundle, extend from one leaf face to the other (Figs. 8–10). The inner flange of each girder insures a uniform distribution of tensions on the adaxial surface in these long, curved, ribbonlike grass leaves; the lower surface is protected from compression by an abaxial development of lateral sclerenchyma between flanges. These mechanical tissues also prevent buckling, breaking across, and laceration, as well as collapse of the blade. Leaf margins, particularly exposed to the risk of tearing, often have special mechanical protection.

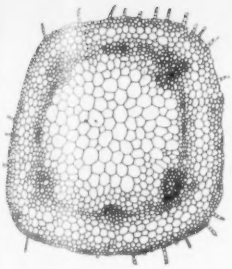
Symmetry in Plant Parts

The harmony or balance in the proportions of members to the whole, the distribution of parts around a line in the body, or on opposite sides of a plane through a body, is designated as symmetry. Since in its strictest sense symmetry rarely occurs in a seed plant as a unit, the term is employed in a somewhat looser sense to plants or is applied only to individual parts. Jay Hambidge observed that the basic line in the design of living things, such as shells, flowers, tendrils, the body of man, the margins of many leaf types, etc., is a logarithmic spiral having the external proportions of 1.618034 to 1.* Hambidge characterized this spiral as the line of dynamic symmetry, a curve suggestive of life and movement.

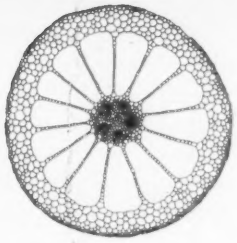
Static symmetry, on the other hand, based upon the pattern properties of the regular two-dimensional figures such as the square and the equilateral triangle, is typical of many plant parts, particularly of their internal organization as observed in microscopic studies. Plant structures that grow vertically are usually radially or bilaterally symmetrical. Radial symmetry characterizes stems, roots, petioles, and most flowers and fruits, as well as leaves of certain xeric species. Parts other than branches of the main axis, which are oriented obliquely or at right angles to the vertical, are frequently bilaterally symmetrical and dorsiventral in tissue organization, showing a definite orientation to the mother shoot

* J. C. Pierce. The Fibonacci Series. *Sci. Monthly*, 73, 224 (1951).

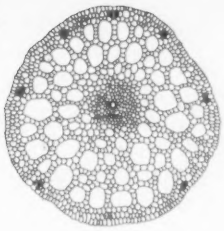
Transverse sections of typical stems of (1) *Coleus blumei* Benth., (2) *Myriophyllum proserpinacoides* Gill, and (3) *Elodea canadensis* Michx.; roots of (4) *Juncus mexicanus* Willd., and (7) *Senecio spartioides* Torr.; rhizome of (5) *Juncus mexicanus* Willd.; haulm of (6) *Juncus mexicanus* Willd.; leaves of (8) *Muhlenbergia pungens* Thurb., (9) *Sporobolus giganteus* Nash, (10) *Andropogon scoparius* Michx., (11) *Sphaeralcea incana* Torr., (12) *Rhus trilobata* Nutt., (13) *Senecio spartioides* Torr., (14) *Salsola kali* L. var. *tenuifolia* Tausch, and (15) *Suaeda suffrutescens* S. Wats.



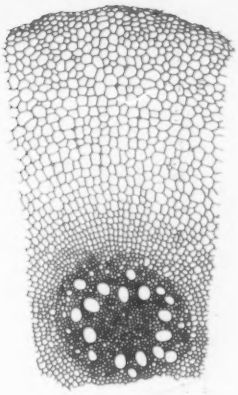
1



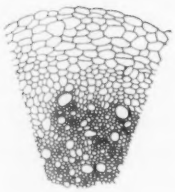
2



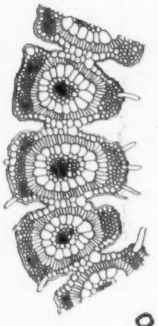
3



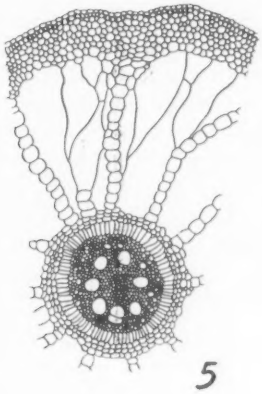
4



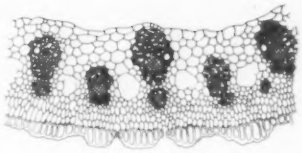
7



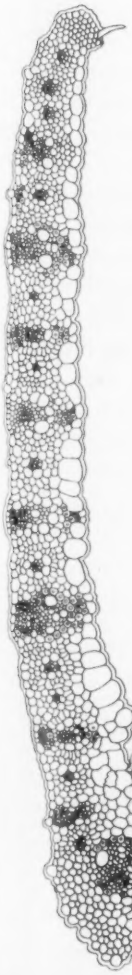
8

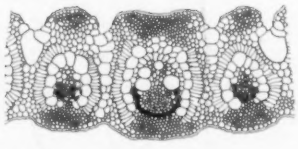


5

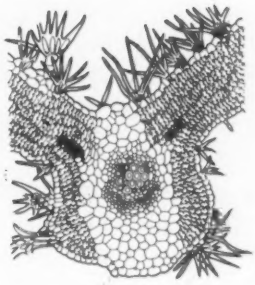


6

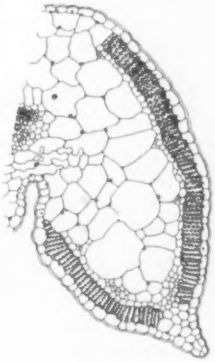




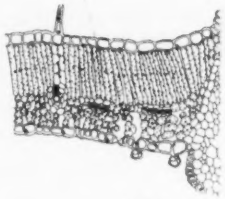
9



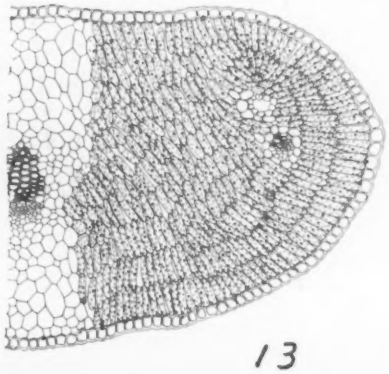
11



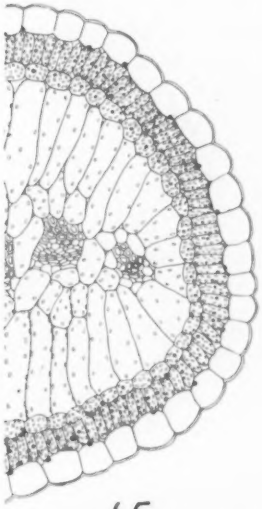
14



12



13



15

10

and at the same time to gravitation, light, and pressure. The dependence of internal tissue orientation on external conditions is most clearly evident in dorsiventrally organized parts, illustrated by the dorsal, vertically elongate palisade layer and ventral spongy mesophyll of the mesomorphic dicotyledon leaf (Fig. 12). Lateral arrangement of such parts around the main axis to form a mosaic typical of the species provides an optimum light exposure.

Surface : Volume Relationships in Leaves

Leaves of plants having a moderate water requirement are commonly large, whereas those of species growing naturally under dry conditions are ordinarily small. Just as short persons are often corpulent and tall individuals are frequently lean, small leaves are commonly thick, and large leaves are thin, the two leaf types exhibiting contrasting external surface : volume ratios. Small leaves, being thicker, expose a decreased transpirational surface per unit volume. Because of the greater leaf number, however, small-leaved plants sometimes expose a greater total external surface than those with large leaves.

The increased thickness and smaller size of xeromorphic leaves are associated with the greater development of palisade cells (Fig. 13), which elongate vertically in multiple rows at the expense of laterally expanding spongy mesophyll. This structural modification results from a limited water supply, high light intensity, or a nitrogen deficiency. Palisade cells of xeromorphic leaves reduce resistance to water movement in the mesophyll. Decreased resistance in the leaves of xeric plants may be more significant than reduction of external surface, which is often illusory. Elongate palisade cells may facilitate transfer of food materials, also, under the stress of a reduced water supply.

The fleshy leaves of succulents are thickened by a dorsiventral development of water storage tissue (Figs. 14, 15) rather than by multiple vertical palisade layers. Water tissues are the first to show evidence of wilting, their radial walls being thrown into folds as the cell shrinks when water is withdrawn by the green photosynthetic cells apparently having a higher osmotic pressure. The main principles of design or art structure—repetition, harmony, contrast, gradation, and unity—are apparent in transverse sections of all leaf types.

A skyscraper stands because the physical stresses have been correctly calculated and relieved. In the course of evolution, principles of construction similar to those involved in the erection of a building or a bridge governed the morphogenetic activities of plants in economically providing requisite mechanical support, in balancing opposing parts, and in equalizing surface : volume ratios for functional efficiency of particular plant structures.

Plato observed that if arithmetic, mensuration, and weighing be taken out of any art, what remains will not be significant. Originally symmetry in art must have been copied from the universal macroscopic symmetrical patterns in living things, since the artist, like the man of science, picks, chooses, and groups from existing elements. Symmetry today has a dubious place in art outside architecture, since symmetric balance smacks of patterns, and newer schools are revolutionary in accord with the times. Balanced, intricately symmetrical designs continue to be produced, however, in the growth patterns of plants and animals. Like the architect, these growth patterns combine in a harmonious scheme the independent and often opposing requirements for mechanical fitness, convenience of function, and economy of constructional materials.

An Evaluation of Science Teaching in Senior High School*

S. R. POWERS

Dr. Powers has been identified with science education at Teachers College since 1923. A native of Illinois and a graduate of its state university, he did his graduate work and started his teaching career at the University of Minnesota. Since his arrival at Teachers College in 1923, Dr. Powers has been engaged in many extracurricular activities, one of which was his election to the chairmanship of the AAAS Section on Education (Q) and as vice president of the Association in 1951.

I

THE criteria for evaluation of science teaching may appropriately be derived from our conceptions of (1) the broad aims of education in a democracy and (2) the unique contribution to these broad aims that is to be made by the science teacher. It will be noted in this discussion that the work of the science teacher is thought of as coordinated with the work of the teachers of social studies and other such specialists. Each is a member of a team that has for its task the education of young people.

In a democracy the broad aims of education are derived from the desires of the people, and these include the desire for survival, comfort, freedom, recognition, and a place of respect in the social group. These are the guides to learning. All of us cherish the belief that, if we personally could have freedom for our efforts our work could be creative. We estimate, or evaluate, our own success in learning by criteria derived from our desires, and evidence of our success may be seen in self-confidence, independence, and in social awareness and participation. Our learnings are derived from our activities, and as the learnings are gained they become parts of our comprehensive view of people, of society, and of the world. This comprehensive view functions as background for assaying the needs in society for services and for estimating the opportunities suggested by these needs, for group action as well as for personal careers. In some such pattern of thinking one may envisage the changes that occur in young people, as they work with freedom to direct their efforts toward winning for themselves a place of respect in the social group.

Working within the scope of these broad aims, the science teacher will try to help young people gain (1) in awareness "of the nature of science and its importance to the total social enterprise;" (2) in realization "of the dual responsibility of insuring that we have enough competent scientists to do whatever job may be ahead, and a voting public that understands and supports the scientists' role in defense and in the design for living;" (3) in extending understanding of science in relation (*a*) to personal and public health; (*b*) to aspects of home and community; (*c*) to far-reaching changes in agriculture, industry, transportation, national defense, and in world relations; (4) in recognizing and personally evaluating the career opportunities in various areas; and (5) in comprehending the world as orderly—that is, describable in terms of relations—and to free themselves from superstitious beliefs and other troublesome misconceptions.

The learnings suggested by these special functions are valid because they are related to, and helpful in, situations that will be met by young people in the normal course of their development. The young person in high school is gaining day by day in his comprehension of "the total social enterprise." Science is important in his life to the extent to which it is important in this total enterprise. He sees as he gains in these learnings the need for specialists and in the process he is challenged to examine the opportunities open to him for a personal career. He recognizes conflicting points of view concerning such matters as public health,

* Based on the address of the retiring vice president of Section Q, delivered at the Annual Meeting of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, December 27, 1951, Philadelphia, Pa.

agriculture, industry, and national defense; and he sees the need for a voting public that can decide these issues on the basis of experience. Furthermore, people, young and old, derive satisfaction from their experiences as they learn that the world about them is not chaotic, but orderly in the sense that it may be described. The student learns, too, that in a world that can be described events may be successfully predicted, and that consequently people can learn to predict the consequences of their action and thus give direction to their own behavior and assume responsibility for it.

These special functions are selected from among those with which we as science teachers are concerned. The preceding statements (as indicated by quotation marks) have been assembled mostly from standard sources, including reports from the President's Commission on Higher Education (*Higher Education for American Democracy*); the President's Scientific Research Board (*Manpower for Research*); and the Educational Policies Commission (*Education for All American Youth*). These functions are recognized as inclusive of many that must be realized as means to the development of young people to be members of a dynamic and self-perpetuating society.

The success of our efforts to realize these accepted functions can be estimated from answers to questions such as the following: Are our students gaining in ability to deal with their own personal questions in such a manner that they do gain confidence and a feeling of security for themselves? Are they gaining a community consciousness, with a feeling for their own responsibilities as members of the community? Are they learning from their experiences about the opportunities open to them for a successful career? Will they examine the opportunities for personal careers as scientists or as engineers? Are they gaining in ability to comprehend from what they experience learnings that are related to what they see as they reflect upon themselves as biological organisms and as they look out from themselves at the world?

The successes suggested by these questions are discernible in behavior. We identify these successes as we work with our students, as we hear them talk, as we listen to their questions and to their planning, and as we learn about the ideals and attitudes that give direction to their activities. As we participate in their activities we learn from them as they learn from us. The behavior that is evidence of these successes is most clearly recognizable in the setting of a whole course of action. Behavior related to school learnings will be readily recognized when students are working with interest and directing their efforts toward goals they have themselves identified and evaluated.

II

But these behaviors are not dissectible. There is evidence over and over that the usual instruments used in testing and evaluating give us but little information about the way our work is affecting the development of our students. These instruments seem to tell us most about native ability and interests. In our choice of tests of learnings we are in considerable measure opportunistic, in the sense that we choose them as means for assigning a grade but with little regard for principles or for ultimate consequences. The nature of the problems to be dealt with in evaluation of science learnings and of science teaching may be seen in some illustrations.

Students in a tenth-grade biology class in a small town in New York were encouraged to examine their interests in community resources and community welfare. They learned or were reminded that their town had been founded as a center of an important lumber industry. The sale of lumber had brought great wealth to the early families. But as time went on the forests were cut and the land, unsuited to agriculture, became largely wasteland; consequently the trend in the flow of wealth was out of and not into the community. During recent years in this and other areas work has been directed toward reforestation, and these young people were challenged to study and apply the methods of reforestation appropriate to their region. The teacher raised the question of the nature and origin of the forests that had been cut for lumber. The students were carried back in time to the glaciers and through the plant successions that, continuing for 25,000 years, became the climax growth that had been the source of wealth for their grandparents. The concepts of succession and climax were carried with them into their studies of how to restore the lumber industry in their community. Many sources were available to them for extending their studies, including the county agricultural agent, state foresters, and old settlers. This was a "non-regent class." This is important only in that with this designation (familiar to all New York State teachers) they were free to follow their own initiative. No syllabus, no Regents' Examination, no standard requirements to block their interests.

The teacher was a long-time member of the community, steeped in its local history, and he was

an active worker in public service. Many if not most of the students had been born within the school district, and many would continue to live there after they had graduated from the school. This study of reforestation was a favorable learning experience for these young people. A cursory evaluation is sufficient to show that they gained community consciousness. This was their community. Within it, for better or for worse, were resources for their livelihood and for their success and happiness in life. They were experiencing the steps by means of which industries are created. They were preparing themselves to take part in these industries and, in the process, to acquire homes for themselves and their future families. In their learning experiences they were actively at work at developmental tasks, and as they worked they were gaining in ability to cooperate with others, in self-confidence, and in a feeling of belonging to the community group.

In this illustration we find a teacher concerned about the public welfare. Specifically, he was interested in better opportunities for young people, better relations among people with differing social backgrounds, better sanitary conditions as a means of reducing the incidence of illness, personal freedom, an improved standard of living, and other improvements that he saw as contributory to a clearer comprehension of human needs and of the means to the realization of these needs. His aims, or objectives, were derived from his interests, and the aims took on specific meaning as they were projected into the community within which he worked. As classes came along, one after another, they brought students with the same general interests, set in the same community. These interests are lifelong. While they were together the teacher and his students cooperated in advancing the common good. Every act was purposeful, every person carried responsibility for contributing to common aims. They helped one another. Thus learning was accomplished.

This situation was real, and the teacher was not unique. It is normal to have such interests and to work toward them when one is free to do so. Students and teacher were well rewarded.

In retrospect it seems clear that, in a situation such as has been described, no amount of testing or examining with the usual paper-and-pencil tests would tell an outsider as much about the quality of the learnings as could be obtained from an observation or from a conference with the teacher. Each student was eager to succeed. Each one was testing himself, and as they worked together they were testing each other. They discovered their failures and were eager to convert them into successes. The over-all evaluation made by the students was that their work was worth doing, that it was interesting and useful. The teacher, aware of the feelings of his students, knew that his work was successful. He gained confidence in himself, and the people of the community gained confidence in him. They liked him for the work he was doing with their children. It seems imperative that no outside standards should be imposed upon this teacher to interfere with his work. From this and from other observations it seems clear that if teachers are to achieve success they must be trusted. Trust is denied as standards are imposed that are derived from outside the situation within which the teacher works.

Other illustrations of teaching in which students discovered their place in the community may be cited. In a medium-sized industrial city students in the chemistry class identified the raw materials that came into the city. They studied these materials and in a measure took part in processing them into manufactured products. This was work in which many of their parents were engaged. They discovered the relations of these processes to community and to personal welfare, and that processing goods was the basis of jobs and of wealth.

In another area the teacher worked on the assumption that people, young and old, seek to comprehend the physical universe, that an individual's conception of the universe influences his opinions about what is valuable in life, and "that it is a responsibility of education to help each person gain for himself a philosophy which takes account of human welfare, is free from superstition, misconception, and paradox and is in accord with scientific knowledge of human beings and the universe." In her work with young people this teacher found support for this assumption. The students were asked: "Do you think that there should be opportunity for boys and girls to discuss questions of this type [the type that would arise out of the above assumption] so that they may learn the kinds of beliefs others hold?" A typical response was: "It is not a matter of 'should there be;' there is such discussion going on every day between students and friends."

An important activity in the work of this class was the reading of a pamphlet entitled *The Spangled Heavens.* In the introduction to this pamphlet, some questions were raised about how one's understanding of the physical universe may affect his notions about himself and about life in

general. The young people recognized these questions as in agreement with questions they themselves had often raised. They were challenged to examine their questions and opinions and the opinions of others about life and the world. During their studies, which included observation, reading, and discussion, these young people experienced many changes in opinion, which were equivalent to changes in personal philosophy and were in a direction away from "superstition, misconception, and paradox" and toward an "accord with scientific knowledge about human beings and the universe."

The teaching in these illustrations was planned and was done with reference to the objectives stated earlier in this paper. The evaluation was done with reference to the same objectives. In agreement with sound educational theory it was assumed that these objectives could be realized. The students participated in activities through which they "extended their awareness of the nature of science and of its importance in the general social enterprise." They saw the need for competent scientists, and some were no doubt challenged to prepare themselves as specialists in some aspect of scientific work. As voters today they will understand something of "the role of scientists in the design for better living." They have "gained in comprehension of what they see as they look out at the world."

Attention was centered in these studies upon the interests and activities of young people. The learnings were sought after by the students, not given to them as tasks to be done under compulsion. The competence of teacher and students and of others who may have participated—together with the facts and principles of science as found in textbooks and in other reading matter—were resources for use by the students in following up their interests.

III

The illustrations just presented are in contrast with teaching situations in which attention is centered upon facts and principles as they are presented in an organized science course, in which the teacher "assigns what is to be learned" and gives tests to find out whether his assignments have been met. The teacher's evaluation of his work is carried in the marks he assigns. The stated objective is to learn a science. The practical objective is to gain a good mark. The stated objective, and the methods used in evaluating success in its achievement, may be at least partly valid for those who are committed to a career in science. Such students may be seeking this kind of learning. In this instance the teacher as consultant helps them to acquire what they seek, and the relations between the teacher and his students may be closely similar to those described above.

It is important to note, however, that not many high school students are seeking such learnings. It seems likely, too, that those who do may have been advanced prematurely and with losses they can never regain. By this early entrance upon specialization they are often denied the opportunity to learn about "the nature of science and its importance to the total social enterprise."

The first courses in high school science were organized as outlines of subject matter and prepared by college teachers. These courses were, in the main, abbreviated college courses. Careful comparisons of the high school and the college course in chemistry, for example, have shown that there was but little that is distinctive about the content of the high school course except its brevity. A careful examination of the textbooks used in the two courses has shown that practically 100 per cent of the high school course was included in the college course. The outlines followed in preparing the texts were the same. The high school courses have been looked upon as the beginnings of education for a career in science. Because of rapid advancements in the sciences, with many spectacular achievements in research, young men have been attracted to these courses.

A standard course in high school chemistry, recommended as appropriate for college entrance, was outlined in 1899 by the Committee on Chemistry of the Science Department of the National Education Association. This committee was under the chairmanship of Alexander Smith, at that time associate professor in the University of Chicago and, later, chairman of the Chemistry Department in Columbia University. His name is well known to chemists. In his treatise on *The Teaching of Chemistry in the Secondary School* (1902), written soon after the publication of the report of his committee he said:

> It is evidently a prominent aim of the teacher at the present day to give his pupils a well-rounded account of chemistry as a science; to give him a bird's eye view of the science as an organized system of knowledge; in fact to show him an outline plan of the results of the science as they appear to the chemist himself. With this purpose in view Avogadro's hypothesis and its consequences, formulae and equations (often with graphic formulae) and many somewhat artificial experiments with strange substances have to play a conspicuous part in instruction.

From then until now "Avogadro's hypothesis and

its consequences" have played "a conspicuous part in instruction."

Theories of learning, and theory and practice in evaluation, indicate that these courses are not valid in terms of the broad aims of high school education or in terms of the special function of the science teacher. A more obvious criticism is based on the observation that the level of achievement in the courses is very low. As more refined measures of achievement are used this observation becomes more convincing.

This criticism of the teaching of special science is not new. In 1854 Francis Wayland, who was at that time president of Brown University, gave his evaluation of the teaching of high school chemistry in an address before the American Institute of Instruction. He said: "I have no doubt that thousands of the pupils of the somewhat advanced schools have gone through a system of chemistry supposing that they have studied that science . . , and whose whole knowledge consisted in the recollection for a few weeks of some of the terms of chemical nomenclature." President Wayland's evaluation has been echoed through the years. If he were here today he would surely "have no doubt that thousands of the pupils of [our high schools] have gone through a system of chemistry supposing that they have studied that science" without having learned the consequences of Avogadro's hypothesis for formulas and equations.

It seems certain that, although the vast majority of our science students learn to pass examinations, they do not learn science. An analysis of the concepts associated with the words they use as responses to examination questions are often naïve, even weird. Concept analysis will reveal that but few high school students will associate with atomic or molecular weight the experimental methods by means of which these are determined. Few will go deeper than to say that atomic weights are got from a table and that molecular weights are obtained by adding the weights of atoms. Such misconceptions are adequate for the examinations they must pass, but they can hardly be other than obstacles to the students' efforts to gain an awareness of "the nature of science and its importance in the total social enterprise."

These beginning courses have never been successful. Only a few of the students who entered the study of a special field of science continued that study into a career. Many who have become career men in a science began their study of that science in college and continued with no apparent disadvantage as compared with those of their classmates who had studied science in high school. The courses were supported for *mental discipline,* and with this support the term "scientific attitude" has become a meaningless cliché. They were also supported as education in fundamentals. It seems likely that these special field courses can never be successful in high school; their objectives are stated in terms that are not consistent with the broad aims of secondary education in America, and they do not furnish the science teacher an appropriate setting for his special functions as outlined earlier in this paper. Obviously there can be no midground. If these courses are not useful, then they are useless and hence wasteful.

The Committee on Physics of the Science Department of the National Education Association, appointed at the same time as the Committee on Chemistry, was under the chairmanship of E. H. Hall, of Harvard University. In his report to the general Committee on College Entrance Requirements, Professor Hall explained that,

> inasmuch as the Physics Committee was made up largely of gentlemen who had written textbooks—very different textbooks—for schools or were in the way of writing such books, I could not undertake to get from them any general agreement as to the details of what a course in schools should be. But as Dr. Nightingale [chairman of the Committee on College Entrance Requirements] insisted on some kind of a report on the subject, I at last sent him what is practically a description of the Harvard requirements in laboratory work as my individual report, at the same time notifying the other members of the Committee of what I had done, and requesting each of them to take corresponding individual action, if he felt moved to do so.

Professor Hall did not report how many members of his committee expressed dissension, but the implication was that there were few or none. The final report stated, "It may be assumed that the list met with approval of those who did not indicate dissent." Hall commented elsewhere that "the list of titles of experiments is precisely the same as that numbered 1 to 61 in the Report of the National Education Association and in the Harvard Descriptive List." It seems from this report that this list of experiments was adopted by default.

These two reports, the one by Smith and the other by Hall, have had dominating roles in determining the plan—including aims, content, and method—of present courses in physics and chemistry, and in its main outline this plan has been followed through half a century. The substance of these reports was incorporated in state syllabi. Textbooks based upon the syllabi appeared during the first decade of this century, and some of these textbooks, following many revisions but still with

many features of the same general pattern, are in use in the schools today.

These courses, in their origins or as they exist today, have not been planned with reference to the aims of education and of science teaching as stated earlier in this paper. Students who take them have but little opportunity to "extend their awareness of the nature of science and of its importance in the general social enterprise." Attention is centered on the relations recognized as within a particular science, with neglect of relations that may be recognized as within the "social enterprise." The determining criterion for choice of subject matter is derived from the questions "Is it chemistry?" or "Is it physics?"

Interviews with students indicate that, following their work in these courses, they do not comprehend the need for competent scientists and are not challenged to prepare themselves as specialists in some aspect of scientific work. In fact, it has been suggested that our general high school and college courses in physics lend *discouragement* rather than encouragement to young people to enter science as a career. It may be observed, too, that their studies have not stimulated them to active interest as laymen in advancing scientific work as a means to better living. The lethargy and open opposition among voters with respect to the President's recommendation supporting a Science Foundation lend support to this suggestion. With the emphasis on assigned subject matter, there is too little opportunity for the student to gain in comprehension of what he sees as he looks out at the world.

In common practice in the teaching of science the discovery of the relation between the world outside and the organized materials of the course is too often left to chance. Teachers sometimes take a defensive position, saying they are not interested in "applications" but only in "fundamentals." It is a safe conclusion that students and people generally are interested in applications and not in what seems to them to be an arbitrary definition of fundamentals. To satisfy their interests they tend to enter courses and careers where there are recognition of and emphasis on human relations and in which fundamentals are defined with reference to these relations.

There are in these observations suggestions of why students shift away from science courses, of why enrollments in science are decreasing, of why there is a shortage of scientists, and of why there is a lack of interest among laymen in advancing scientific work as a means to better living. The work in science courses in our secondary schools and college is not directed toward these ends. Neither have the plans for teacher-education in science been drawn with reference to the needs of young people fifteen to seventeen years of age. We often hear that "the teacher must know his stuff." There can be general agreement on this point, but there may be strong disagreement as to what "stuff" he should know. What is really basic?

I quote once more from Alexander Smith. He discussed at some length the "necessary preparation" of the chemistry teacher. With all the force at his command he wrote as follows (*op. cit.*): "The first constituent of this necessary knowledge of chemistry is general chemistry. If we ask what the second ingredient must be, we should be compelled to say again general chemistry, and the same answer must be given at every repetition of the question."

Smith commented further that it is "knowledge of the science as a whole that is important to success in elementary instruction." He suggests that the teacher's first year of study should be devoted to general chemistry, the second to advanced general chemistry, to include "qualitative analysis and determination of molecular weights, the measurement of equivalents and combining weights in which the refinements of quantitative analysis are employed. . . ." Organic chemistry was suggested for the third year, and inorganic preparations for the fourth.

These suggestions for the education of the chemistry teacher are in close agreement with recommendations in the two yearbooks on science teaching, the *Thirty-first—Part I* (1932) and the *Forty-sixth—Part I* (1947), of the National Society for the Study of Education, and in the Report of the Cooperative Committee on Science Teaching of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

An evaluation of our plans for the education of science teachers supports the conclusion that we have been largely opportunistic. We have accepted traditional plans without questioning their adequacy for specified purposes. We have repeated the recommendations of Alexander Smith that if one is to teach science he must know science. This has been interpreted as equivalent to saying that if one is to teach science he need know only science. This interpretation has had strong support from the examination requirements for teacher certification. It is time that this interpretation be challenged and that the needs of the science teacher for professional education be viewed in relation to the total setting of his work. If we may agree that the

function of the teacher is to help young people deal with tasks that they necessarily meet in the course of their development, then we may use this as a criterion for defining what is basic in teacher education.

It is suggested that the success of the science teacher be estimated on the basis of his ability to use science, not merely to recite it. As a means to helping young people use science in their lives he will learn to use science in his own life. Through such experiences the perspicacious teacher will gain an awareness of the nature of science and of its importance in the general social enterprise. He will learn to recognize and evaluate the opportunities for specialization in science and will learn to recognize the public issues that are to be decided by vote. Only as he is educated in these matters will he be able to assist (and to refrain from opposing) young people in their work. These learnings suggested for the teacher are like other learnings in that they are gained by doing.

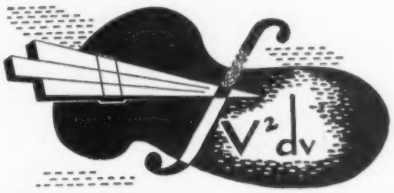
IV

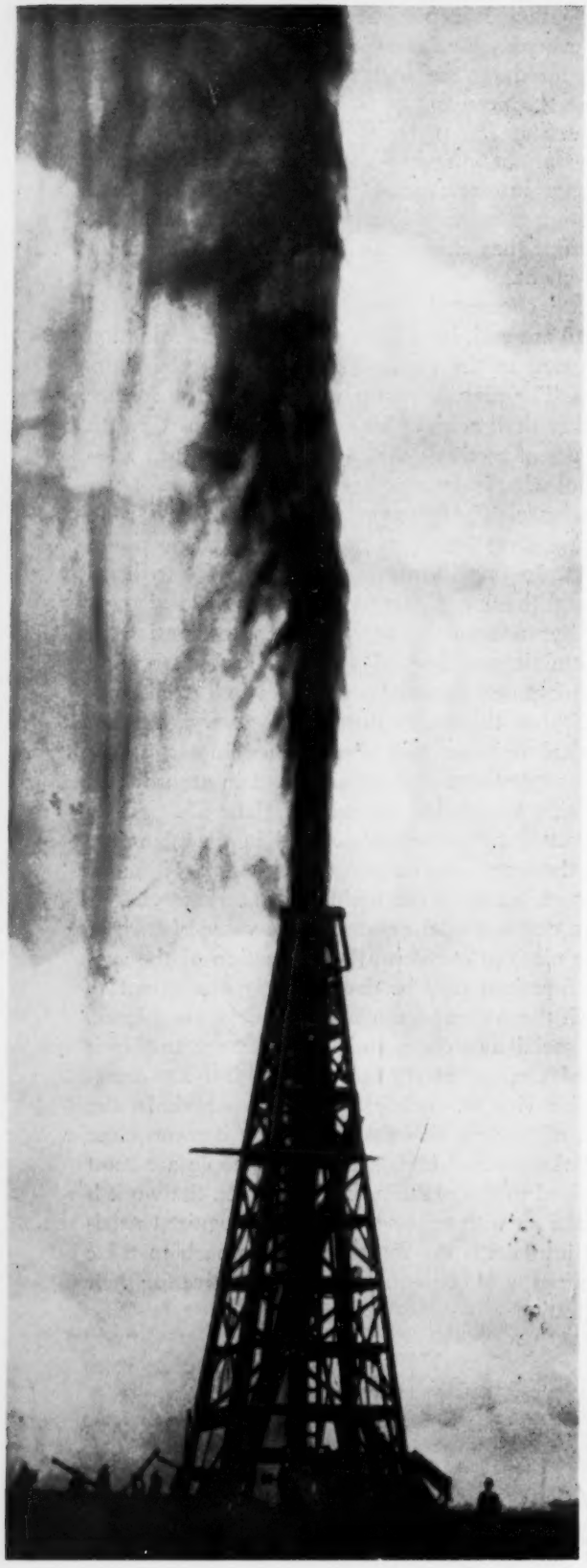
In this discussion I have attempted to say that as teachers we must work within the setting of American democracy, and that the traditions and aspirations of local, national, and world peoples give meaning and substance to the broad aims of education. In an evaluation of science teaching we are challenged to ask ourselves if we are recognizing this setting. Are we educating young people to make decisions, to take action with recognition of consequences, and to evaluate these consequences in terms of their own and the total welfare? Or are we merely—or mainly—asking them to follow our directions or the directions set forth in a book? The learnings achieved by these alternative methods are sharply in contrast.

In this evaluation of our work as science teachers we are challenged to ask also if we are recognizing our functions as specialist teachers and working most effectively toward their realization. These functions are defined with reference to activities related to the "total social enterprise." They are illustrated by reference to personal and public health, home and community, agricultural production, transportation, and other features of our everyday life. The special functions are further recognized by the fact that young people learn about the need for special services, about the opportunities for personal careers, and about the need for an informed voting public as they participate in these activities. Still another special function is to help young people comprehend the relations that exist among the things in their environment.

Two contrasted patterns of teaching, both of which are real, have been presented for evaluation as means to the realization of these special functions. The plan in one pattern is that the science teacher shall achieve his special functions through the use of methods that are directed toward mastery of what is described as the basic subject matter of science. The plan in the other pattern is to achieve these functions by methods that are more direct. In one illustration the plan was to learn through having a part in reforesting a local community; a second was through participation in maintaining a flow of raw materials into, and manufactured materials out, of an industrial community; a third was through discovery that the physical universe can be described in terms free from superstition and paradox and in accord with scientific knowledge. In each of these illustrations the young people were involved in the planning, and the work was carried on with recognition by them of its relation to their needs and interests.

An estimate of the comparative value of each of these plans as means to the realization of the special functions may be derived from the extent to which the students gain in self-esteem, confidence, and social awareness and in the extent to which their learnings become incorporated into a comprehensive view of society and of the world. In the light of modern theories of learning it seems clear that the method in which young people are most involved in the planning and in which the work is carried on with concern for their recognized needs and interests is the most direct approach to these learnings, and consequently most effective for their realization.





PETROLEU

OIL is a product in everyday use, not only in automobiles, motor boats, locomotives, ships, and oil burners but also in furniture polish, house paint, pharmaceuticals, carbon paper, soap, and many other products—in fact, there are currently in use more than 1400 products made from petroleum or petroleum derivatives.

The multiplicity of uses of petroleum is due in large measure to the success of petroleum research and technological developments through the years. Research is carried on in every phase of geology, geophysics, chemistry, physics, engineering, and metallurgy as applied to the discovery, production, and refining of petroleum. I shall attempt here, in the space allotted, to summarize briefly the more important technological developments of the petroleum industry over the past thirty years.

Geological Exploration

The rise of systematic geological exploration for oil took place in the period 1910–25. Prior to this, the discoveries of petroleum were more or less accidental. The requirements for the accumulation of oil were finally recognized as:

1) A buried source bed of clay and shale or lime at one time containing decomposing organic matter that in later years was converted into petroleum;
2) A neighboring porous and permeable bed or reservoir rock into which the oil from the source bed was squeezed by the pressure of the overlying sediments; and
3) A trap in the reservoir rock to which the migrating oil could flow and where it would be retained over geologic ages until penetrated with a well drilled by modern man.

Figure 1 shows several typical oil traps. The two on the right are structural, having been produced by large tectonic movements or earthquake faulting. The one on the left is a stratigraphic trap arising from a lenticular sand pinch-out embedded in nonpermeable shale, and with no especial structural relief. From a study of outcrops combined with other available information, such as electric and radioactivity well logs and paleontological data on fossils, geologists are able to map horizons below the surface and often can predict the presence of a structural trap. In most areas, however, the outcrops are insufficient for subsurface geology and the tools of geophysics must be employed. From purely statistical considerations, many geolo-

—Then and Now

PAUL D. FOOTE

At present executive vice president and director of research of the Gulf Research & Development Company and vice president of both Gulf Oil Corporation and Gulf Refining Company, the author of this résumé of petroleum research has had a long and distinguished career. Even a summary of the high offices he has held would fill more space than is available here. Dr. Foote is a member of the National Academy of Sciences and a fellow of the American Association for the Advancement of Science. His article is based on an address delivered on the occasion of the presentation of the 1951 Pittsburgh Award (by the Pittsburgh Section, American Chemical Society) to William A. Gruse, of Mellon Institute.

gists believe that possibly half the oil accumulated in ancient sediments must be located in stratigraphic traps, of which East Texas, Glenn Pool, and Burbank are good examples. These, except by accidental discovery, can be located only by combining precision geophysical methods and fundamental geological studies. Even then, the chance of detection is small, and at present a vast amount of basic research is being directed toward a means for discovering such hidden deposits.

Perhaps one of the most important problems in exploration for oil is the recognition of buried source beds, since without the source beds there will be no collection of oil in either stratigraphic or structural traps. The source material had to be organic, both plant and animal. Petroleum may occur in rocks that are much older than the first vertebrates and before the first trees developed; hence fish and complex plants are not essential. Primitive organisms such as algae and diatoms were sufficient. Bacteria and other low forms of life are capable of producing hydrocarbons from organic matter in the presence of a reducing environment that is initially alkaline, such as the water of the ocean. The source beds of petroleum are, accordingly, fine-grained sediments and muds deposited in the sea, or perhaps in an alkaline lake if the sediments develop into sufficient thickness. It is the province of geology to delineate the areas where millions and hundreds of millions of years ago thick sedimentary deposits were being laid down, together with primitive animal and vegetable matter, in alkaline water. This work must be done in three dimensions, for the physical conditions may be vastly different in each successive geologic epoch. The entire period in which we are interested certainly embraces a billion years.

Geophysical Exploration

Thirty years ago, geophysics was an academic subject unknown to the petroleum industry. Today it is the key word in oil exploration. The early geophysicists devoted to oil prospecting were of necessity well trained in the basic sciences and were avid students of earth physics as well as being professional practitioners. Their problem was to learn to measure, and to understand the implications of, the variation of all the many physical properties affected by the shape and constitution of the earth's crust.

The first experimental work was done in the United States during the very early twenties by a group that included E. A. Eckhardt, now vice president and associate director, Gulf Research & Development Company. In this research artificial and miniature earthquakes were initiated by dynamite explosions, and the waves arriving at various seismometers were recorded at a central

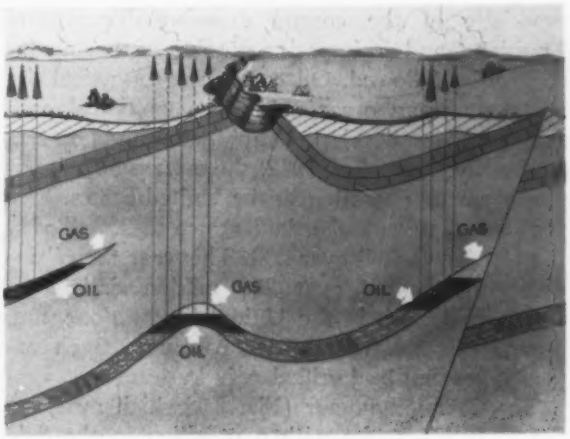


FIG. 1. Typical oil traps.

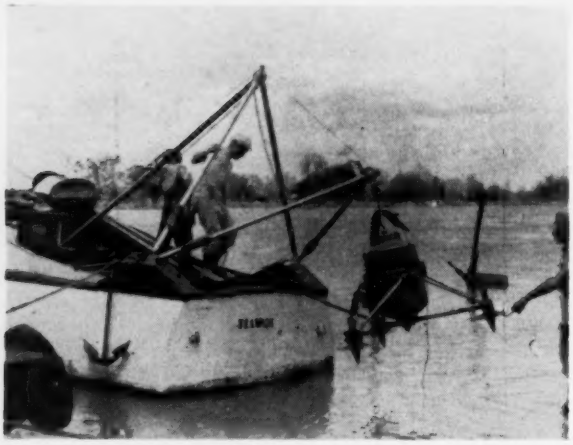


FIG. 2. Gulf gravimeter for underwater exploration.

station. These experiments were technically successful, but they did not lead to immediate commercial use. The first commercial surveys in the United States were made by Mintrop's Seismos Gesellschaft for the Marland Oil Company late in 1923 and for Gulf early in 1924. Gulf made the first discovery by this means—the Orchard Salt Dome in coastal Texas, later developed into an oil field.

The first gravity instrument used by the oil industry in exploration was the Eötvos torsion balance. At about the same time in the closing months of 1922, the Rycade Oil Company (Amerada) and Roxana Petroleum Corporation (Shell) each received a torsion balance from Europe. In the early spring of 1924, Rycade found the Nash Dome, the first oil structure and oil field to be discovered in the United States by any geophysical method. It preceded Gulf's discovery of Orchard Dome by only a few months.

These early successes led to rapid expansion in the use of the seismograph and the torsion balance, especially in the coastal areas of Texas and Louisiana, and an imposing number of spectacular discoveries followed. Oil company geophysical departments were organized, and geophysical contracting firms developed rapidly in number and in size. By the end of 1932, there were 50 seismograph parties operating in the United States. Five years later, this number had grown to 250. Today the number is well over 500. This year the oil industry will spend over 200 million dollars on geophysical work in the United States alone, and double this for world-wide operations. Such expenditures can be justified only by results.

The Gulf gravimeter (Fig. 2), which measures the force of gravity with a precision in the field of 3 parts in 100 million, was placed in service during 1935. The Gulf flying magnetometer (Fig. 3), for measuring and recording the earth's magnetic field to 10^{-5} gauss from a plane flying at 200 miles per hour, was commercialized during World War II. Recent developments in the seismograph (Fig. 4) involve the recording of the movement of the earth with a spread of as many as 400 detectors placed in a geometrical pattern or array. The mathematical geophysicists have developed methods of interpreting the data so obtained in terms of structure to a depth of several miles. It is now possible to make stratigraphic maps, similar to the ordinary topographic maps, for a horizon at a depth of perhaps 2 miles, with a precision of possibly 20 feet in favorable areas.

Drilling and Production

Edwin Drake drilled the first well for the specific purpose of finding oil, in 1859, near Titusville, Pennsylvania. It is a far cry from the Drake well, which was only 69½ feet deep, to the wells of today that range downward to nearly 21,000 feet, or 4 miles. Most of this progress has been made during the past thirty years. The Drake well was drilled with cable tools, a method that persists even now in Pennsylvania and other Eastern states. Over the years it was developed and improved until a well 10,312 feet in depth was drilled in Pennsylvania in 1949. In 1901 the Lucas well at Spindletop, Texas, ushered in the rotary method of drilling, which has made it possible for the oil industry to keep pace with the demands for more and more crude petroleum. Here, also, a prepared mud was first used to carry the cuttings to the surface. It was made by cows milling around in the water pit. In those early years, the successful completion of a well was signalized by oil spouting high over the derrick to soak everything in the vicinity. Today, a well is completed without any outward evidence of the tremendous energy that has been harnessed.

Our modern well-drilling practices are the result of continuous technological improvements in materials, equipment, and methods. Metallurgists have provided steels with the necessary physical properties, and engineers have developed processes to fabricate them into drill pipe, casing, and tubing for deep, high-pressure wells. These scientists also have teamed up to provide the rock bits to drill and core the hard formations encountered in deep wells and to develop the surface control equipment —master valves, blowout preventers, "Christmas trees," etc.—that makes it possible to bring in a well safely and without loss of oil and gas.

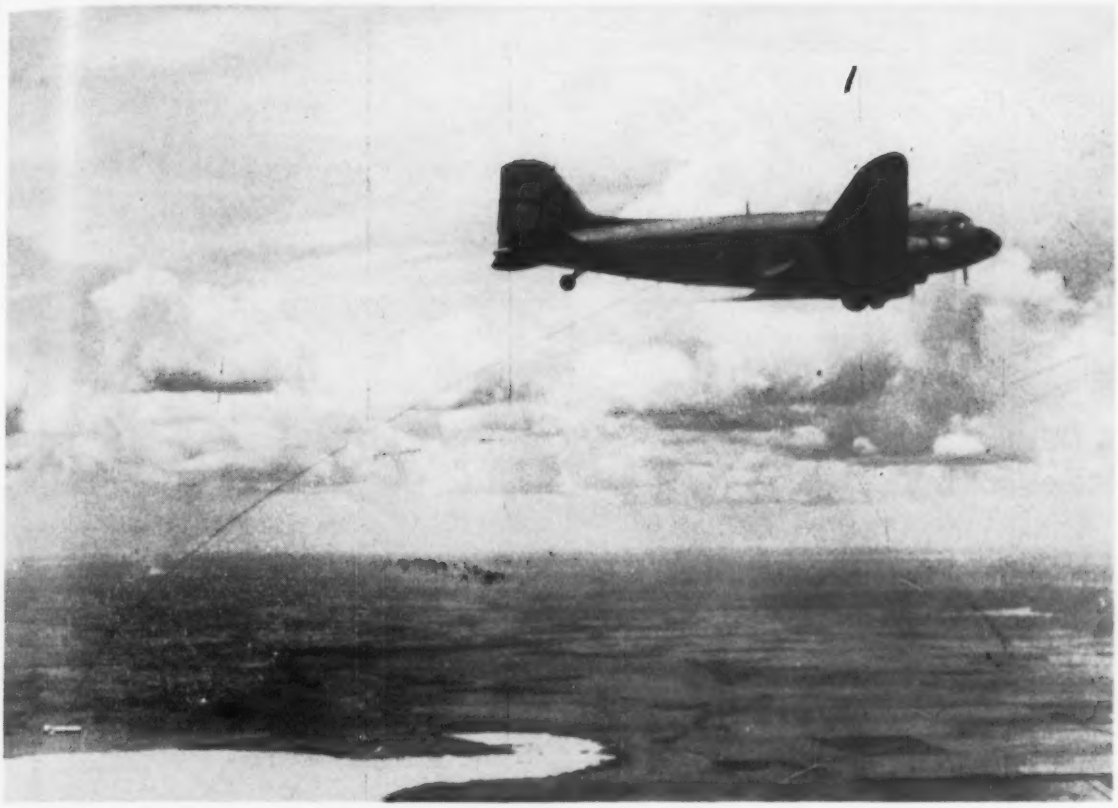


FIG. 3. Gulf flying magnetometer.

During this same period, colloidal chemists made an essential contribution by the development of drilling muds of sufficient density to control the high pressures in deep wells, to carry the cuttings to the surface, and minimize the caving of the walls of the bore hole. More recently, chemists have provided special drilling muds, such as the silicate–salt-water muds, which are particularly effective in preventing the heaving of shales and are unaffected by contamination with formation brines. Other examples are the oil-base and emulsion-base muds used to insure maximum productive capacity from formations containing clays that swell on contact with water. The oil-base muds also permit more accurate analysis of the cores of the formations penetrated and, hence, a more reliable estimate of oil reserves.

Electrical engineers and electrochemists have partially filled the need for more information about the strata exposed in the well by the development of electrical and radioactive logging techniques. By these tools it is possible to correlate the formations from well to well and to distinguish among shales, water-bearing sections, and potential oil-bearing formations. There is a possibility that further progress in well logging may reduce substantially the amount of expensive coring now necessary.

As the search for oil extended to the marshes of the Mississippi delta, engineers solved the problem of unfavorable surface conditions by mounting the drilling rig and auxiliary equipment on barges that could be towed to the location through dredged canals, sunk to rest on bottom during the drilling, refloated on completion of the well, and towed to the next location.

Drilling of the tidelands of California and later of Texas, Louisiana, and Mississippi was accomplished by supporting the equipment on a platform on top of piles high enough to be above the level of the waves during severe storms. It was no mean feat to design these for safety against waves and winds under extreme conditions. More recently special floating equipment and structures have been constructed for drilling in the open Gulf of Mexico in more than 50 feet of water. In spite of these advances, overwater drilling would not have been economically profitable without a method for controlled directional drilling that permits the sinking of several wells from a single

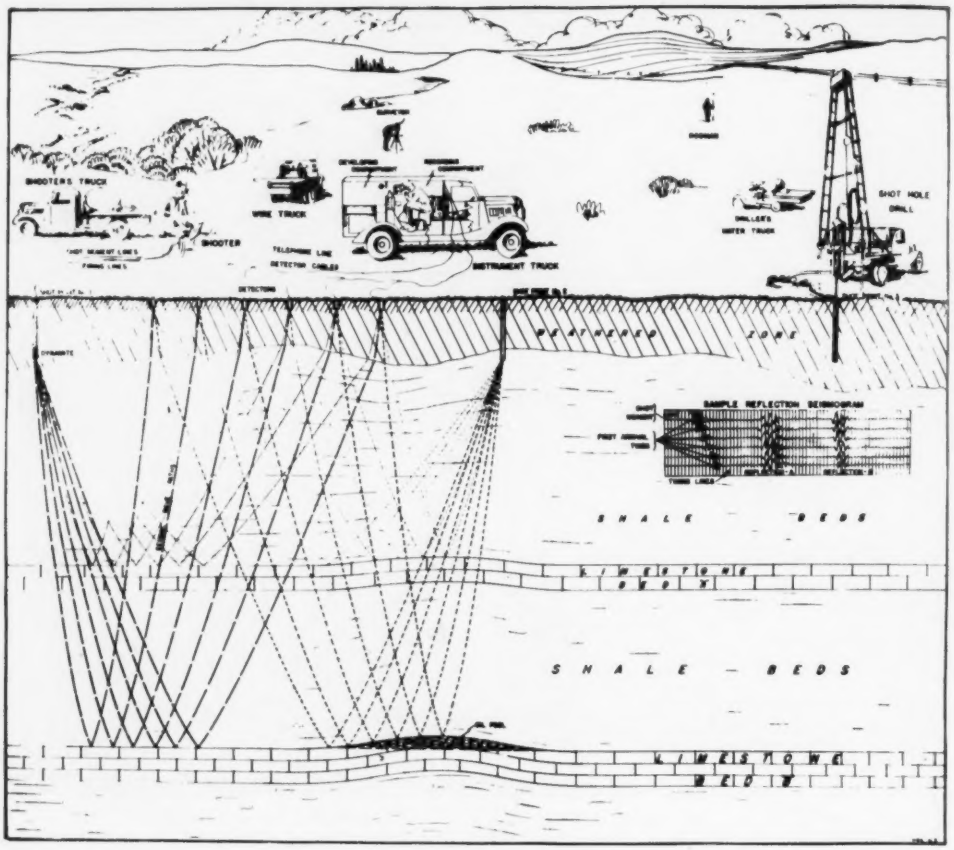


FIG. 4. Seismograph operations.

platform. As these overwater platforms cost almost a million dollars, the economic importance of this development is readily apparent.

Today drilling technologists are faced with numerous new problems, among which two of the most important are: how to drill wells cheaper, and how to drill to 30,000 feet. Thirty years ago the wells in a field were worked at maximum capacity. It was not long before they began to produce water and then ceased to flow. In the late twenties thoughtful people in the industry came to a realization that perhaps this unsatisfactory sequence could be modified advantageously if more were known about the conditions in an oil reservoir and the physical principles that governed the flow of oil into a well. Gulf and other companies decided to explore this new technological field. Physicists were brought into the production and research departments, and the science of reservoir engineering was born.

Pioneering investigations—both theoretical and experimental—led to the derivation of the laws of flow of fluids in a reservoir. It was shown that the production of the wells in a field could be regulated so as to insure the efficient utilization of the energy available in the reservoir, whether it came solely from the release of gas dissolved in the oil or was augmented by the pressure of water following the oil. It was also shown that the recovery from a gas-drive field would be lower than from a water-drive field. Although some early attempts had been made to increase recovery by air or gas injection, maintenance of vacuum, or injection of water, it became possible to predict the results to be expected from these measures by the application of the mathematical theories developed by the reservoir engineers. Since it was thus feasible to calculate the economics, an impetus was supplied to secondary recovery projects, such as pressure maintenance, repressuring, or water flooding. Under the open-flow practices of thirty or more years ago, the ultimate recovery ranged from 20 to 40 per cent of the oil in place. By application of the principles of reservoir engineering in both primary and secondary stages of production, it is now possible to recover 60–90 per cent of the available oil. Each barrel of extra oil so produced is equivalent to the discovery of a barrel of new oil. Reser-

voir engineering has made a major contribution to conservation.

The studies of reservoir behavior provided the basis for determining the minimum number of wells required to drain a reservoir effectively. Thus optimum well spacing was accepted as a basic concept for efficient and economical operations. It has been a potent factor in unitization or voluntary pooling of leases in a field, for it eliminates the expenditures for unnecessary development wells and, in the case of secondary recovery projects, unnecessary injection wells. Unit operations conserve capital, equipment, manpower, and operating cost.

Meanwhile, physical chemists were busy investigating other phases of the pressure-volume-temperature relationships of hydrocarbon systems. Many of the deeper reservoirs were found to exist as a single gas phase, and these reservoirs were subject to the phenomenon of retrograde condensation. Numerous gas cycling projects were undertaken to maintain reservoir pressure above the retrograde condensation pressure and thus to insure maximum recovery of this nearly white crude oil of high gasoline content.

Concurrently, petroleum engineers and chemists were developing better well completion techniques, aids to faster and more complete recovery, such as acid treatment of limestone formations, chemical water shut-off treatments, well cementing, hydraulic fracturing of the formation, improved emulsion-breaking chemicals, economical artificial lifting methods for deep wells, labor-saving automatic equipment, and inhibitors effective against corrosion of well and surface equipment.

Space does not permit a proper tribute to the technological accomplishments which in the short span of the past thirty years have placed the drilling and production branches of the oil industry on a firm scientific foundation.

Refining

In the early days, crude oil was simply distilled for straight-run gasoline and for the higher fractions of kerosene, heating fuel, and lubricants. But with the rising public demand for powerful automobiles, such as Reo the Fifth (Fig. 5), which R. E. Olds claimed as the final word in luxurious design, it appeared evident that the 10–20 per cent gasoline fraction obtained through distillation would not be in sufficient volume to satisfy the requirements. Known crude reserves were limited. In fact, one of the great geologists of that early period was awarded an honorary degree for having the courage to predict that oil would be exhausted within a decade. Scarcity of gasoline might therefore force up the price to a point where it would stifle development of the automobile industry or divert it to the use of steam or storage batteries.

William M. Burton, of the Standard Oil Company of Indiana, after two years of intensive research, finally developed a process of thermal cracking some of the heavier fractions of the crude, thereby doubling the yield of gasoline. Figure 6 shows the first experimental Burton still, and Figure 7 a battery of Burton stills in commercial operation. Stills such as these produced 200 million barrels of gasoline before they were supplanted by newer methods of cracking.

LIFE MAGAZINE - 1911
Reo the Fifth
$1,055
Center Control
Brake and Clutch Pedals
30-35 Horsepower
Wheel Base—112 inches
Wheels—34 inches
Demountable Rims
Speed—45 Miles per Hour
Made with 2, 4 and 5 Passenger Bodies
One Front Door Open to Show Center Control
Top and windshield not included in price. We equip this car with mohair top, side curtains and slip-cover, windshield, gas tank and speedometer—all for $100 extra. Self-starter, if wanted, $25 extra.
The Car That Marks My Limit

FIG. 5. Reo the Fifth.

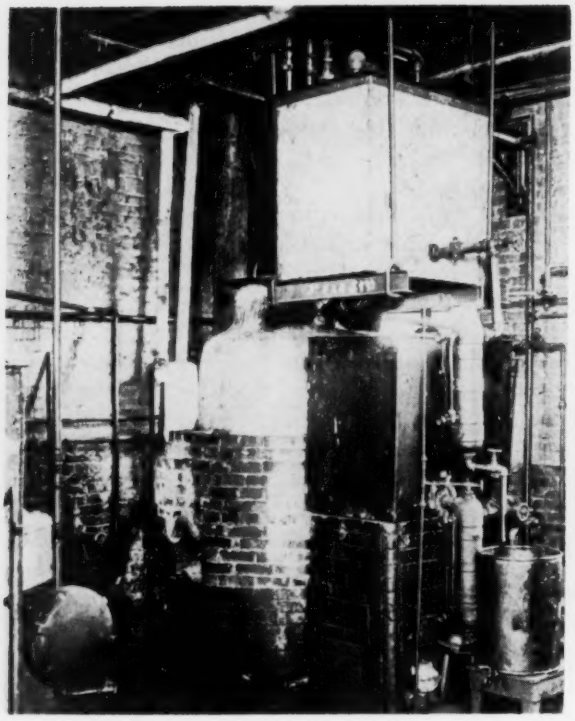


Fig. 6. First Burton experimental still.

No industry is more highly competitive than petroleum refining, and this work immediately stimulated intensive effort on the part of every oil company to develop new and better methods of thermal cracking with higher yields of gasoline. Work on thermal cracking of heavy oils to gasoline was undertaken by Gulf at Mellon Institute in 1911. Figure 8 shows the Gulf polyform system of thermal cracking in its modern version, with large yield and high octane number to satisfy the demand of the high-compression internal-combustion engine. In this process, the stream of oil passing through the cracking chamber is augmented by large volumes of light hydrocarbon gases. While the heavy molecules are cracked or broken into gasoline constituents, simultaneously the gas molecules are joined together or polymerized to increase the yield.

There is an old, old story of the Arab who bequeathed to his three sons, respectively, one half, one third, and one ninth of his fortune. Upon his death, his property consisted of seventeen camels, which number obviously is not divisible by two, three, or nine. A sheik who was called in to settle the dispute agreed to add his personal camel to the lot, making a total of eighteen, whereupon, by the terms of the will, one half, or nine camels, was awarded to the first son; one third, or six camels, to the second son; one ninth, or two camels, to the third son. The camels thus distributed were nine plus six plus two, or seventeen. Lo and behold, one camel remained as the property of the sheik (Fig. 9). Great is the power of Allah! The eighteenth camel made the entire distribution possible yet played no final role in the reaction. That is the definition of a catalyst, and catalytic chemistry has become the motivating agency in modern petroleum refining.

The first high-quality catalytically produced gasoline was manufactured by the Gulf aluminum chloride process as developed by Gulf's A. M. McAfee shortly after Burton's discovery. Figure 10 shows a commercial plant. Because of high operating costs, this method was superseded by the Houdry process, using a fixed bed catalyst consisting of pellets of synthetic clay. Although this type of cracking combined with thermal cracking was responsible for much of the base stock for aviation gasoline during the second world war, cyclic regeneration of the catalyst every twelve minutes required inherently costly design of reactor and valving. As a consequence, two newer methods of catalytic cracking, employing a continuously regenerated moving bed, were developed. One of these was the thermofor process of Socony-Vacuum, in which a large column of pelleted catalyst was allowed to fall by gravity through the reactor zone. Into this moving column, the vaporized cracking stock was introduced, and the various products were withdrawn as continuous streams. The spent catalyst from the bottom of the reactor was transported by bucket elevators to a regenerator kiln and from there was returned to the reactor. More recent modifications have employed an air lift or pneumatic conveyor for handling the catalyst. Figure 11 shows Gulf's 30,000 barrels per day thermofor unit at Port Arthur, Texas.

The other and most extensively employed method is the fluid catalytic cracking process, in which the catalyst is in the form of a finely divided powder. This powder is supported on the oil vapors in the reactor and by the combustion gases in the regenerator, and is in a fluidized state throughout the entire process. The combination of the vapors with the finely divided catalyst behaves hydrodynamically precisely as a liquid having half the density of water, and flows through a system of pipes and vessels constituting a plumber's dream (or nightmare). Figure 12 shows the largest fluid catalytic cracking plant in the world, 60,000 barrels per day, located at Gulf's

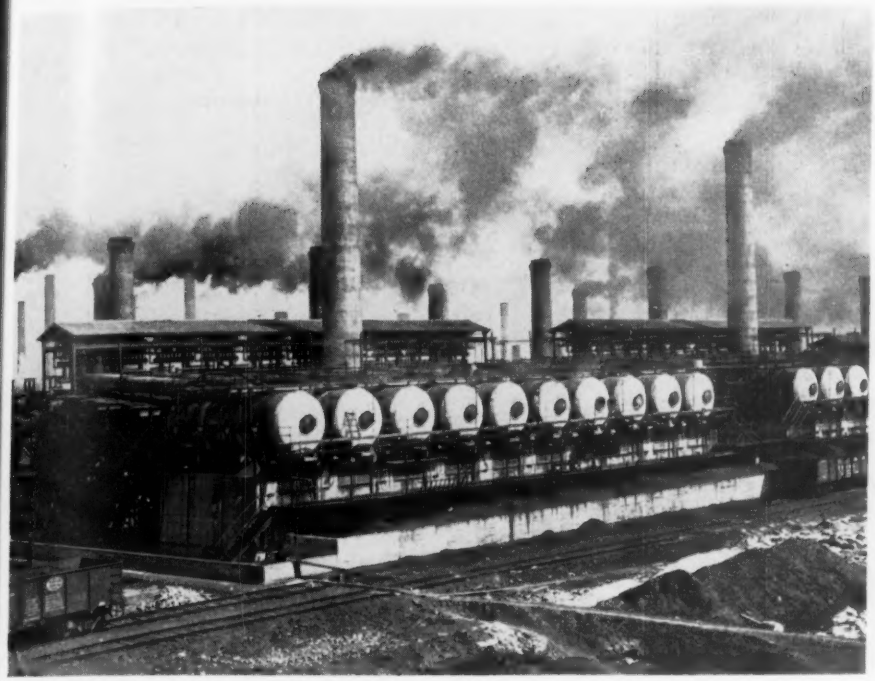


FIG. 7. Battery of Burton commercial stills.

Port Arthur refinery. The surface area of the catalyst passing through the reactor in a single day is approximately 2 million square miles.

Catalytic cracking is only one of the many new catalytic processes of the petroleum industry employed for the volume production of liquid fuel. Merely the names are formidable enough without going into detail. A few of these are sulfuric acid alkylation of paraffins, olefin polymerization, aromatic alkylation, catalytic reforming, hydroforming, isomerization, hydrodesulfurization, aromatization, hydrogenation, and dehydrogenation. These and numerous other processes, such as solvent extraction, solvent dewaxing, acid, clay, and alchlor

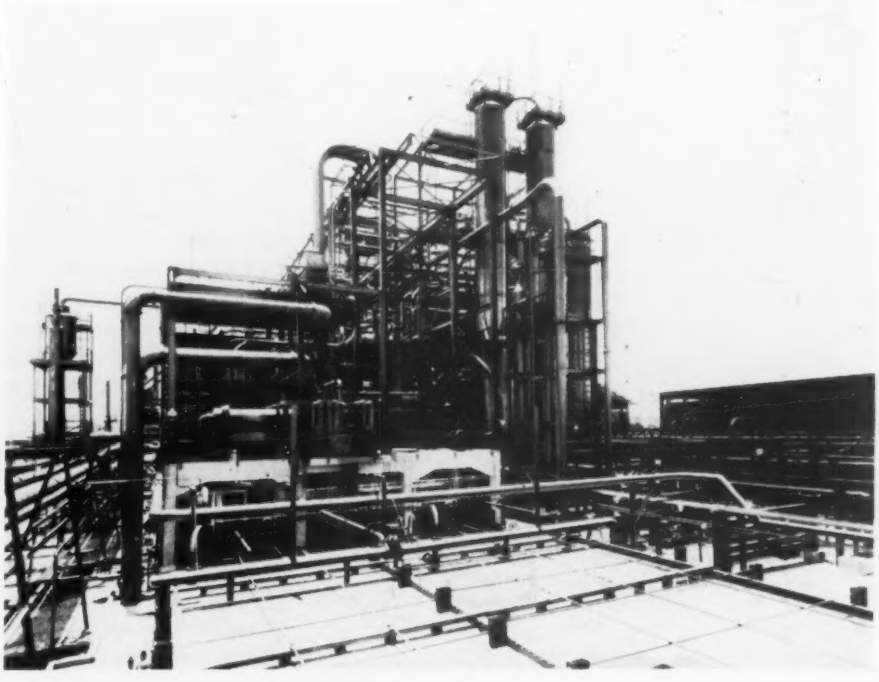


FIG. 8. One of Gulf's polyform process units.

treatment, and sweetening processes, make petroleum refining one of the most involved activities of the entire chemical industry.

Over 90 per cent of the hydrocarbon molecules in military aviation gasoline were not present in the original crude oil but are made synthetically by processes unknown even in the laboratory of twenty years ago. Motor gasoline contains about 60 per cent synthetic molecules. The exact arrangement of the atoms within a molecule is of the utmost importance, and refining is directed toward the production of the more effective orientations. For example, it would be quite possible to manufacture two gasolines, made of a long series of components, having for each gasoline the same empirical formulas and in identical percentages, one gasoline that would satisfy the requirements of the highest compression motor ever developed, and the other that would wreck an ordinary engine within a hundred miles—if indeed the engine could be made to turn over at all. Yet with all this organic chemistry and chemical engineering, because of the tremendous volume of production, we are able to purchase gasoline, less tax, for the price of bottled drinking water. This is the outstanding achievement of our generation; the result of chemical research in the laboratory. It is the reason the oil companies of this country are willing to invest more than 100 million dollars annually in research.

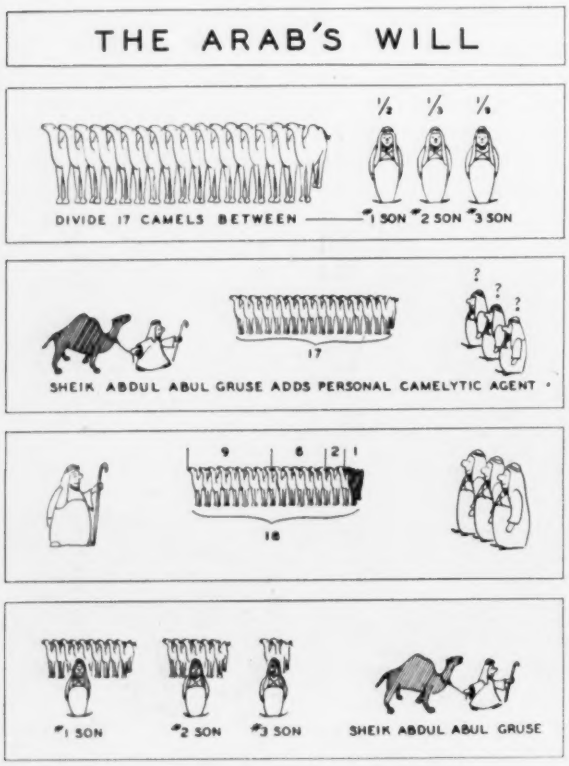


FIGURE 9.

Product Development

Gasoline is the major product of petroleum, and research is constantly directed toward obtaining, at the lowest possible cost, the maximum volume yield of suitable octane number, volatility, and balanced performance for the internal-combustion motor. Currently, intensive research is concerned with attempts to develop gasolines that do not permit the formation of deposits in the combustion chamber that may give rise to knocking or preignition. After a few thousand miles of driving, a new automobile usually requires a much higher octane gasoline because of these deposits, which can be minimized by suitable chemical addition agents in either the gasoline or oil, or both. Other research on gasoline includes investigations of compositions to reduce formation of gummy deposits in the lubricated section of the engine.

Fuel oils, including distillate fuels for domestic heaters and furnaces, jet engine fuel, Diesel fuel, and residual fuel, constitute the next major group of petroleum products. Improvements in domestic fuel are being made by additive agents to prevent sludges that clog the fuel lines and nozzles, and to increase the stability of the fuel in storage, a problem that has become more serious with the development of catalytic cracking. Two Diesel electric locomotives were in use in 1924. The present number is about 14,000, representing approximately 50 per cent dieselization of American railroads. The problems of Diesel fuel are prevention of sludging in storage, provision of rust-preventive properties, and adequate ignition quality. High sulfur content of Diesel fuel does not cause excessive wear, combustion deposits, or corrosion if the lubricating oil contains certain types of oil-soluble detergents. Research on residual fuels for steam boilers and gas turbines is largely directed toward the development of additives to neutralize the corrosive effects of vanadium on steel. At present fuels of low ash content to reduce deposits, and low vanadium content to reduce corrosion, must be selected for gas turbines.

After all the economical refining methods for the production of lubricating oils have been utilized, the following improvements in performance properties may be obtained by the use of special additive agents: Inhibition of oxidation; prevention of corrosion of alloy bearings; reduction of wear and rusting of engine parts; keeping engines clean; reducing detrimental effects (wear, corro-

FIG. 10. Gulf catalytic cracking plant (McAfee process).

sion, and deposits) of sulfur in gasoline and Diesel fuels; low congealing temperature; low temperature coefficient of viscosity; elimination of foaming. These additive agents reduce the maintenance cost of an internal-combustion motor, minimizing fouling, bearing corrosion, and wear. Similar improvements of industrial lubricants, greases, technical oils, waxes, and insecticides are effected by special compounding with small amounts of chemical additives developed through research.

Petrochemistry

One of the most sensational of all large-scale commercial developments has been the rise of the petrochemical industry, in which petroleum hydrocarbons are converted to chemicals and chemical intermediates. Thirty years ago almost no chemicals were made from petroleum. Today the industry is rated at 2 billion dollars, and the production is 16 billion pounds per annum. Production of petrochemicals is now 100,000 times, production just twenty-five years ago. Growth in the past ten years has been 1500 per cent. Today about a quarter of all chemical production starts with petroleum, and a fourfold increase is expected in the next ten years. This rate of growth is startling because it is inconsistent with the rate of growth of general industrial production, which, during the past decade, was only about a fortieth as much. In this period even the plastics industry grew only about half as fast as the over-all petrochemical industry. The reasons for this industrial revolution are interesting. Let us look at a few of them.

Chemical intermediates from petroleum have found a substantial portion of their markets in the displacement of materials from agriculture. Improvements in agricultural methods are not being applied rapidly enough to take proper care of the growing population—5000 a day increase for the United States, and 60,000 a day for the world. Synthetic fibers from petrochemicals have reduced land requirements for fibers about 2 per cent. If the 1.5 billion pounds per annum of ethylene now being obtained from petroleum had to come from the fermentation of vegetation, we would require over 2 million acres of our best land for the pur-

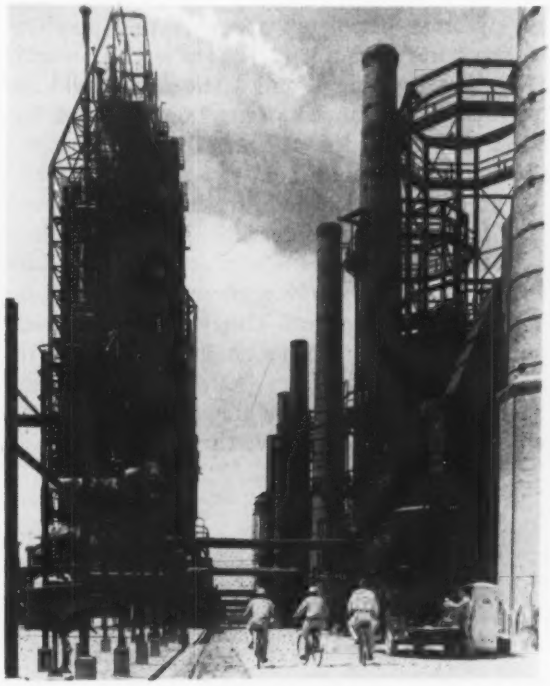


FIG. 11. Gulf's thermofor cracking unit.

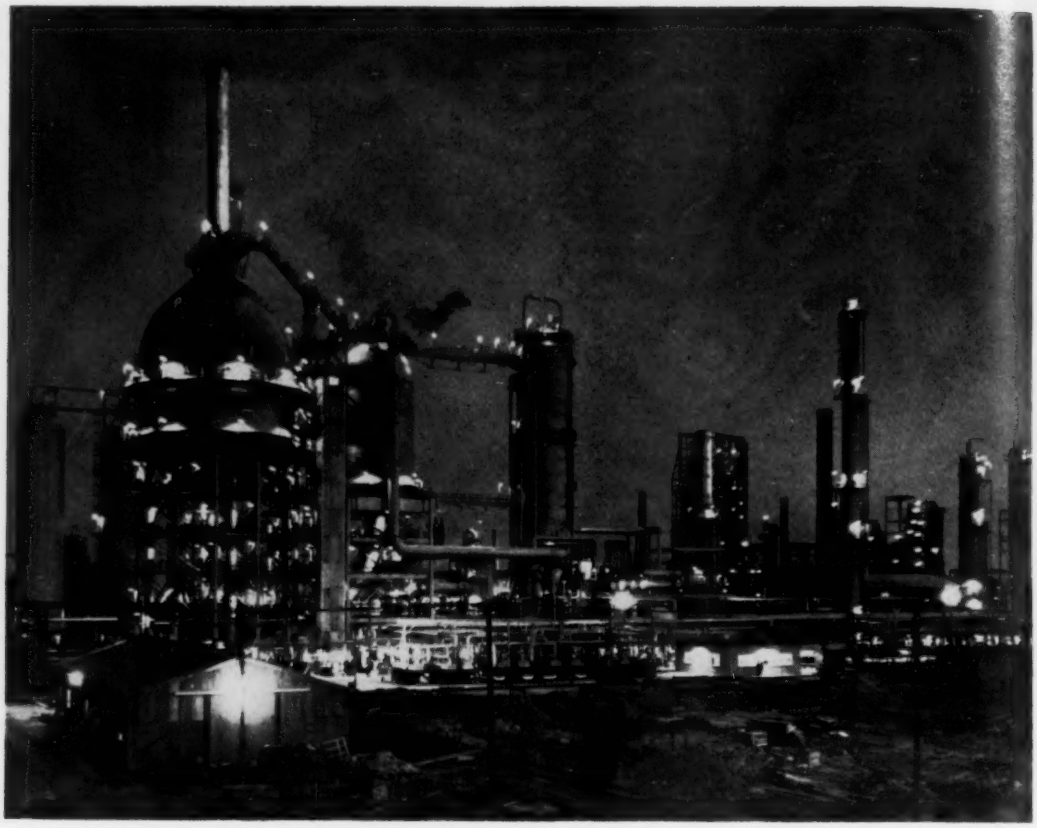


FIG. 12. One of Gulf's fluid cracking units.

pose. The billion pounds of detergent now made largely from petroleum are liberating another 2 million acres of cropland. The present production of synthetic methanol and acetic acid would have required the balanced production of wood from 6 million acres of forest. These few examples could be multiplied many times.

The petrochemical industry has been an important factor in the conservation of our resources. Less than thirty years ago all synthetic methanol was made from coal. Now more than a third of it is made from petroleum. Thirty years ago, all ethanol was made by fermentation. Now more than half of it is made from petroleum. These shifts have been stimulated by the fact that, although other commodity costs have risen substantially during the past thirty years, costs of petroleum hydrocarbons have remained about stationary. At the same time great advances have been made in methods for the synthesis of needed materials from ethylene and other simple petroleum derivatives.

It is not necessary to supply a superficial catalogue of chemical intermediates now manufactured in bulk from petroleum. The briefest description of some 5000 commercial finished products from petrochemical intermediates would require a book of considerable size.

In conclusion, this résumé is necessarily a hopelessly inadequate historical background of a field to which many outstanding men have devoted their scientific careers.

Mysterious Crater Elegante

ALLAN O. KELLY

Mr. Kelly lays no claim to being a scientist, but such careful observers of natural phenomena as he—amateurs though they may be—have often been of incalculable assistance to scientists in many fields. The great men of the Royal Society in the seventeenth and eighteenth centuries were only too glad to accept the help and the firsthand observations of talented amateurs, in their search for "the knowledge of causes and the secret motions of things."

HIDDEN in the environs of Pico del Pinacate, one of the wildest parts of northern Sonora, Crater Elegante is a natural wonder that few people have seen. In fact, few had even heard of it until Wilson McKenney wrote an article describing it (*Westways* [December 1951]). Being intensely interested in this phase of geology, I thought I knew something about most of the craters of the world, but here was a new one scarcely 400 miles from my own doorstep.

Most of McKenney's story has to do with the Papagos Indians and their sacred cave on Pico del Pinacate, but he also mentions nearby Crater Elegante. According to McKenney, this crater was first described by Carl Lumholtz, who explored the area in 1909 and wrote a book about it—*New Trails in Mexico*. He also tells us that the following year William T. Hornaday went to the same area to obtain specimens of the Gillard bighorn mountain sheep for the American Museum of Natural History. He says that both Lumholtz and Hornaday "exhausted their vocabularies in praise of the beauty and magnificence of this crater." It seems, however, that all their praise was not sufficient to entice other travelers to this forbidding and trackless desert, for few places on the continent were as little inhabited or as hot and lacking in water.

Now all this is changed. A good paved highway leads south from Gila Bend, Arizona, to the little border town of Sonoyta and on to Puerto Peñasco, popular fishing village on the Gulf of California. Water, food, and gasoline are available in these towns, and during the winter months the climate is delightful. Crater Elegante lies about 15 miles to the northwest of the paved highway and about halfway between the Mexican border and the gulf (Fig. 1).

When I read about the crater I immediately determined to go there, because McKenney's description and the one picture in his article led me to believe that it might be of meteoritic origin, in spite of the fact that it was located in a volcanic area. My son William and a college friend, Fred Barth, were on Christmas vacation at the time and, being as excited as I at the prospect, decided to accompany me. After gathering together food and camping equipment, the three of us set off on December 29 in a rainstorm, to find and explore Crater Elegante.

We were told at Sonoyta to turn off the highway at Espinosa's Ranch and that Sr. Espinosa would give us further directions. We found the ranch house easily enough, it being the only house between the border and the gulf, but Sr. Espinosa was not at home. His cook, who had recently arrived from Los Angeles, had never heard of Crater Elegante, but he assured us that the road that left the pavement in front of the ranch must be the right one—there was no other road anywhere thereabouts. (He also told us that several jeeps had recently gone that way, but that none had ever returned.)

With this encouraging bit of information, we started following the jeep tracks through a wilderness of brush and cactus. The road wound around among the cactus and the mesquite bushes in a general northwesterly direction, and was never straight for more than a hundred feet or so. Rainfall had been unusually heavy during the summer, so that the desert flora was lush and green. The giant saguaro is the outstanding feature of this landscape, although the organ-pipe and graybeard cactus run it a close second. Ironwood and paloverde trees line the dry washes, and mesquite and creosote bushes dot the landscape in between.

The only signs of animal life were a large flock of some kind of sparrow, a few ravens, a lone jackrabbit, and the common black beetle known in Spanish as *pinacate* (after which the peak is named). This black beetle, when disturbed, stands on its head, points its peak to the sky, and emits a stinking smell well calculated to drive away its

enemies. Apparently the early Spanish explorers were reminded of the *pinacate* when they saw the sharply pointed volcanic peak, and so named it.

A few miles from the ranch, the road passed close to a volcanic rock protruding from the desert floor. We stopped to climb part way up this rock in order to view the plain to the northwest, where we knew the crater to be located, but nothing that looked like a crater rim was visible. We resumed

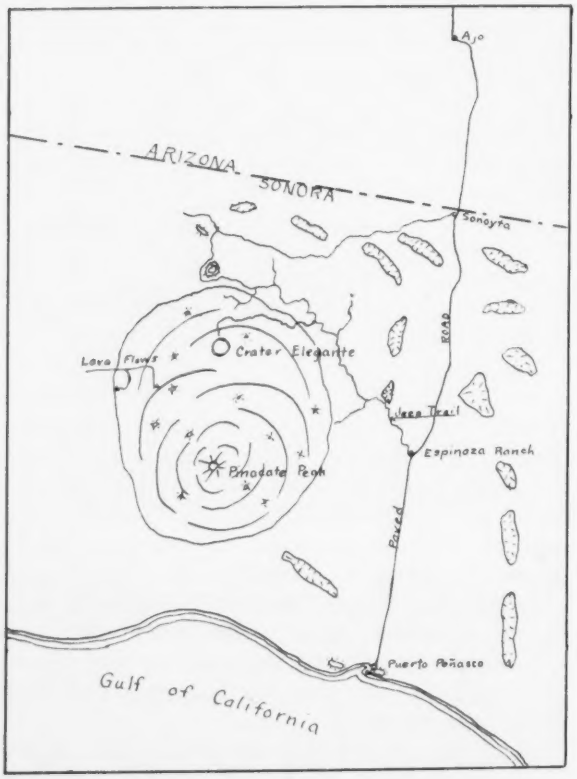


FIG. 1. Sketch map of crater area.

our journey of ups and downs and roundabouts for perhaps another ten miles, until we reached a cinder cone rising abruptly from the nearly level desert. We climbed to the rim and found a small crater, but nothing that answered the description of Crater Elegante, so we continued to follow the jeep tracks. After another hour of driving we came to an intersecting road and a small sign reading SONOYTA. As it was noon, we stopped for lunch and considered where to go next. It seemed clear that the jeeps that had never returned had taken this way to Sonoyta. Why, we could not imagine, but we knew that we must backtrack over our route and try some of the fainter trails leading off from the jeep tracks. After exploring several trails that branched into other trails, we hit upon one that led toward a smoothly rounded hill that looked less rugged than the surrounding lava beds and cinder cones. This trail ended in a gulch at the foot of the hill, where we found two bales of alfalfa hay. This made me sure we had taken the wrong trail again, that this was just a camp where some cowman had brought hay for the saddle horses at roundup time. We had been looking for the jeep tracks made by McKenney a few months before, but finding the hay seemed to make it clear that we were not on the right trail.

Although it was getting near time to make camp, we decided to climb the hill and make another search for the crater rim that McKenney had described as rising about 80 feet above the plain. It was possibly a thousand feet up the slope to the top of the hill and perhaps 175 or 200 feet in vertical rise, but only in the last few yards did we realize that we were approaching a rim. Then we came suddenly upon a tremendous chasm (Fig. 2). It was breathtakingly magnificent! The wild beauty of the scene was enhanced by the storm clouds hovering around Pinacate Peak to the south and by the approaching darkness.

We had only a few moments in which to pitch camp before dark but we could not resist scrambling down the talus slope of the upper crater bowl and looking over the sheer cliff. This cliff we judged to be about 200 feet high. It is composed of five separate lava flows, interspaced with thin beds of ash, and extends entirely around the crater. At the top of the cliff we saw evidence of the great heat that had been generated. The surface of the old lava rock had been remelted to a depth of half an inch or more in exposed places along the lip of the cliff, and the flow pattern of this surface was very plain. Also, it appeared that the upper layers of rock had been blasted back horizontally a few feet, leaving striated markings on the slippage surfaces like the "slickensides" found in clay fault planes. In other places the melted surfaces along the lip of the cliff had flowed down over the side in icicle-like objects several feet in length. This surface melting did not appear further down the face of the cliff, so far as we could see.

We reached our pickup truck about dark and just as it began to rain, but after some scurrying about we got a shelter up, a fire made, and a hot stew cooked for supper. In the morning the sky had cleared, so I ascended the rim to take pictures and to view the crater from various points. The entire circumference of the rim is nearly level except for a rise of about fifty feet on the eastern side where an old cinder cone was neatly cut in half by the catacylsm that made the crater. This cinder cone has a small crater in its top which is

two or three hundred feet across and half as deep. The arc of the big crater cuts the little one exactly in half.

Walking along the west rim of the crater, we came upon several rings of stones that looked like campfire pits except that no signs of fire were evident. At the foot of the slope we found the remains of fire pits with ashes and with the rocks split and blackened by fire. Also, along the top of the rim we found crosses with points of equal length like the cardinal points of the compass, but laid out to point northwest-southeast by northeast-southwest. These crosses were about four feet in diameter and made of stones six to eight inches in diameter; all had the same desert glaze as the surrounding boulders. When lifted out of place, they were found to be slightly embedded in the ground and to have the typical cream color on the underside that is common to lava stones and boulders all over the Southwest. Apparently the rings and crosses are of considerable age and were probably put there by the Papagos Indians when they frequented this region.

We did not walk entirely around the crater rim but went far enough to see that at least two thirds of its outer slope was perfectly symmetrical; and we judged by the continuing level rim on the south side that its outer slope was symmetrical too. It is very likely that the bisected cinder cone on the east side marks the only interruption in the outer slope.

We made no attempt to go down to the crater floor because our time was limited, but we did see what looked like a fairly easy staircase under the north shoulder of the cinder cone. We climbed down to the edge of the sheer cliff in two places and walked along it for some distance, where we saw the same evidences of heat that were mentioned earlier.

Crater Elegante seems to have an unusually large variety of plant life as compared with the surrounding desert. Many of the plants were in bloom or nearing that stage. A kind of tiny lupin covered most of the ground between the boulders. It grows only an inch or two high, and its foliage is a brownish-purple, matching the glaze of the lava rocks. The flower stalks were no more than half an inch long, and the blue flowers were so small that one had to get down on the ground to see that they were lupins. Desert enthusiasts call such flowers "belly flowers" because of the necessity of getting down on one's belly to view them.

At the edge of the cliff and downward over the side,we saw a new plant that we did not see elsewhere; apparently it likes cliff walls and only grows in such places. Growing out of the crevices in the dark lava walls, this brilliant green plant is an astonishing contrast to the other desert plants, which are generally of a gray or gray-green color. It looks like some hothouse or tropical plant. Its leaves look as if they were freshly varnished or covered with dew as they sparkle in the sunshine, and even in the heat of the day they look as if they were covered with dew. It grows from twelve to eighteen inches tall and looks very like a geranium, so far as the leaves are concerned, although the stems are somewhat large for the rest of the plant, like many of the desert succulents. The flowers are small and individual, with green petals and yellow centers hardly more than an eighth of an inch across. There was a small daisy blooming among the rocks, many barrel cactuses with brilliant red spines, and the little pincushion cactus with its tiny scarlet fruit. Big saguaros were growing from the most unlikely places in the cliff and on the crater floor below; also the fiery ocotilla (not then in bloom) and many other friends of the desert.

FIG. 2. Crater Elegante, within easy access of the paved road connecting Ajo, Arizona, and Puerto Peñasco on the Gulf of California in Sonora, is a subcircular depression much like Meteor Crater near Winslow, Arizona, in size, form, and relationship to the surrounding country.

We looked in vain for meteorites; like good explorers, we had hoped to come home with a truckload of these valuable specimens from outer space. However, a small magnet would pick up quantities of magnetic material almost anywhere it was touched to the ground. If there are iron

meteorites in this area, they will be rather difficult to find because of their similarity in color and texture to the lava boulders that cover the surface everywhere. Meteor Crater in Arizona, by contrast, is blasted out of white sandstone, and any dark object like a meteorite is at once visible.

Crater Elegante is especially mysterious and interesting because it has so many of the physical aspects of a true impact crater and yet is located in the midst of a volcanic country. McKenney spoke of the sheer walls of granite—one of his statements that led me to believe the crater might be of impact origin—but I saw no granite within the crater or on its outer slopes. I did see some granite mountains about 30 miles to the east and north.

McKenney's party measured the depth of the crater by aneroid barometer and found the rim to be 975 feet above sea level and the bottom 365 feet above sea level, leaving a difference or depth of 610 feet. He judged the diameter of the crater to be about a mile, an estimate with which I would agree, although people usually underestimate such things. Experience has shown that very few people overestimate the size of Meteor Crater in Arizona, probably because there is no other object of known size with which to compare it. It is really more than 4000 feet in diameter, yet many people seeing it for the first time estimate it at less than half that amount. If the estimate of one mile is correct for Crater Elegante, and it proves to be of meteoritic origin, then it will be second in size only to the Chubb Crater in northern Quebec among the world's recognized impact craters.

The ratio of depth to diameter of crater is one of the best ways to distinguish an impact from a volcanic crater. Volcanic pits, whether made by explosion or by subsidence, are much deeper in comparison with their diameter than impact craters. Volcanic explosive craters are usually V-shaped, often nearly as deep as they are wide, and nearly always located on the top of a mountain. Subsidence craters, or *calderas*, are wider in proportion to their depth, usually in a ratio of about 6:1. Crater Lake in Oregon and El Caldera in the Canary Islands are outstanding examples of subsidence craters, being roughly irregular in every outline. Crater Lake, for example, is thought to have been caused by the slumping in of the top of a volcanic peak perhaps 15,000 feet in elevation. This *caldera* is four miles wide by six miles long and over 4000 feet in depth, with irregular walls both inside and out, and the rim is very uneven. The bottom is also uneven, having a secondary volcanic intrusion called Wizard Island at one end of its pit. The irregular shape of explosive craters and *calderas* is probably due to the fact that as pressure builds up (or gives away in the case of a *caldera*) the rock structure gives away along fault planes or at some point where several fault lines may come together from different angles, so the resulting crater is more or less irregular in shape. Fault planes are straight, as the word implies—or perhaps jagged—but never circular. A perfectly circular vertical fault would be something close to a geological impossibility.

The impact crater, on the other hand, is first made round by the entering projectile (whether that projectile be perfectly round or not), and the following explosion throws the broken material upward and outward in a symmetrical pattern. Ballistic experiments have shown that such a projectile makes a round crater even though it strikes at a considerable angle from the vertical, and that the *ejectamenta* are thrown out in a nearly symmetrical pattern.

The time involved is another important factor. The volcanic crater may be the result of several explosions, or a continued subsidence, or a combination of both. The meteor crater is made instantly. When some visitor from outer space, traveling many miles per second, is suddenly stopped by the earth, its kinetic energy is released instantly as heat and explosive action. Naturally, the results are quite different. If Crater Elegante were located in a nonvolcanic area, it would be assumed at once to be an impact crater, but under the circumstances it will probably take quite strong and positive proof to convince most geologists that its origin is other than volcanic.

The profiles of the three craters (Fig. 3) appear to be quite dissimilar, probably because of the difference in the size of the projectiles that made them, a difference in velocity, and the kind of rock penetrated. It is likely that the larger the projectile and the higher its velocity, the wider and flatter the resulting crater. This is true of the craters on the moon, which are generally considered to be of impact origin.

The Chubb Crater (as described and pictured in the January 1952 issue of the *National Geographic Magazine*) has a symmetrical bowl without abrupt walls of any kind. It was formed in hard granite rock and has a ratio of width to depth of 8.8:1. Arizona's Meteor Crater, which is the smallest, has a U-shaped bottom that slopes upward in one sweeping curve ending in a cliff at the top of the rim. Its ratio is 7.3:1.

Crater Elegante, between the other two in size,

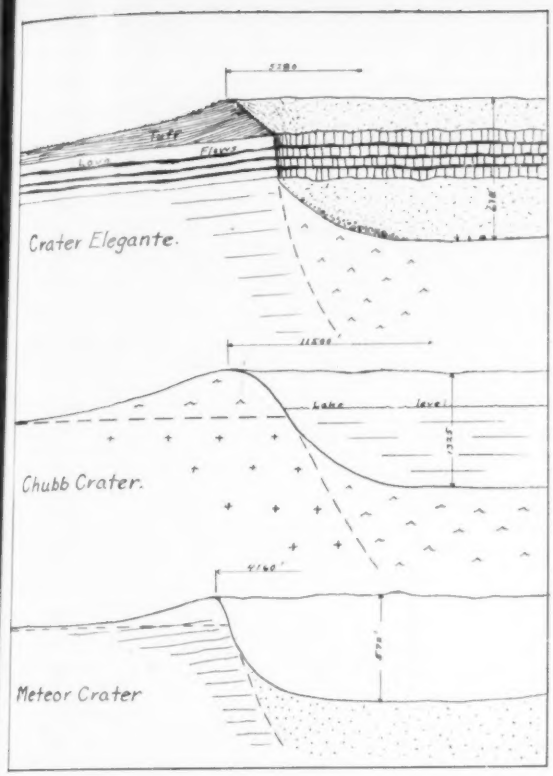


FIG. 3. Estimated profiles of Crater Elegante, Chubb Crater, and Meteor Crater.

has a ratio of 8.6:1 (if our estimate of width is correct), which makes it fit the theory. The difference in profile of the inside of Elegante and the others may be due to the difference in rock types. The upper layers of cemented ash, or tuff, were blown out at an angle of about 35 degrees while the hard lava flows stood up as cliffs (Fig. 4). Although only the lip of the cliff shows signs of surface melting, it may be that the blocks in the talus slope below, which have fallen off the face of the cliff, will also show this surface melting. The whole upper part of the crater bowl seems to be made of thin layers of tuff that were already in place when the explosion occurred. This softer material above the hard lava blew out at an angle, whereas Chubb and Meteor craters were both blasted out of a uniform material and hence are different in profile.

Another mark of the impact crater is its depth below the surrounding land surface. Most volcanic craters are on the top of some mountain, or what remains of the mountain, and seldom if ever are the bottoms of such craters lower than the surrounding country. If there is such a volcanic crater, I do not know of its existence, for even those found in the ocean—such as famous Krakatoa in the East Indies—have craters whose pits are still above the ocean floor. It is typical of the impact crater, however, to have the bottom of its pit well below adjacent areas. This is true of all the known meteor impact craters in the world, and it is also true of Crater Elegante. I would judge its crater pit to be at least 400 feet below the surface on the west and south and about 300 feet below the surface on the north and east.

The upper rim of Crater Elegante, both inside and out, is covered with a uniform layer of lava boulders. The largest are hardly more than three feet in diameter, and the average would be nearer ten inches. There are no piles of boulders, and this uniformity of distribution is what gives the outside of the crater its smooth appearance, so different from the surrounding jumble of lava flows and cinder cones.

Judging by the lack of erosion in the comparatively soft tuff rim, the time of this cataclysm was not long ago. My guess would be that it occurred not more than three or four thousand years ago, although I have seen one storm cause more erosion in our California desert mountains than is evident in this crater rim. It may be, however, that this desert region at the head of the gulf is not subject to the heavy storms and cloudbursts that are experienced farther north.

We examined a good many samples of magnetic

FIG. 4. Approximately one mile in diameter and 610 feet deep, Crater Elegante has been formed in horizontal, cliff-making lava flows capped by poorly cemented volcanic tuff. Pinacate Peak rises in the background.

material without finding any of the tiny droplets of iron that H. H. Nininger has found in the soil around Meteor Crater. These little spherules of iron, which need a good magnifying glass to bring them into view, are thought to be the result of partial vaporization and condensation upon impact. Crater Elegante being larger than Meteor Crater, it is logical to suppose that vaporization took place there also, although the striking body might have been only a stony meteorite that left no trace of iron. It is well known that meteorites vary greatly in iron content, some being nearly pure nickel iron, others partly stone with a sponge-like network of iron running through them, and still others almost entirely stony with only a trace of iron. Lack of meteoritic iron around a crater, then, is not sure proof that it was made by volcanic action. Thorough investigation around Chubb Crater failed to show any meteoritic iron on the surface, yet a magnetic survey showed a strong magnetic anomaly at one point under the rim, indicating the presence of deeply buried iron. In view of these facts it would seem that Crater Elegante should be given a thorough investigation with modern scientific instruments to determine the true nature of its origin. We had only half a day to spend at the crater, so our examination was very limited in scope. We can only report what we saw and hope that it will result in a more careful investigation.

SMO ON THE AIR

Station	Sponsor	Time
	Sunday	
KLBM, La Grande, Ore.	Baker-Union Department of Health (Research Report)	10:15 A.M.
	Monday	
WOI-FM, Ames, Iowa	Iowa State College of Agriculture and Mechanic Arts (Articles of Interest)	7:45 P.M.
	Tuesday	
WEVD, New York City	Wendell W. Rázim (Science for the People)	9:00 P.M.
	Wednesday	
CKPC, Brantford, Ont.	The Telephone City Broadcast Limited (Modern Science)	9:45 P.M.
	(Irregular)	
KBER, Baker, Ore.	Baker-Union Department of Health (Research Report)	....

The Editor of THE SCIENTIFIC MONTHLY will be glad to cooperate with university or other educational stations interested in securing scientific material suitable for broadcasting.

The Viewpoint and Progress of Comparative Vertebrate Physiology

F. H. McCUTCHEON

The author (Ph.D., Duke, 1936) has taught undergraduate or graduate courses in physiology for students majoring in zoology, entomology, ecology, ornithology, parasitology, animal husbandry, game management, physical education, home economics, biochemistry, and nutrition at North Dakota State College and at the University of North Carolina; for majors in liberal arts and in general sciences and for students of human medicine at Duke University; and for students of animal medicine at the University of Pennsylvania. Experience with students of such varied biological interests, together with research work in the comparative and developmental physiology of hemoglobin and respiration, has drawn his attention to fundamentals of comparative physiology. This paper was first prepared to appraise the comparative viewpoint for those interested in animal physiology at the University of Pennsylvania, where, since 1947, Dr. McCutcheon has been professor of physiology and head of the Department of Physiology and Pharmacology in the School of Veterinary Medicine.

TEACHING and research in physiology are now required to consider the viewpoint of comparative physiology as distinguished from general and special physiology. General physiology deals with the functions common to all plant and animal species; special (e.g., human) physiology deals with the functions in limited categories, such as species or genus; whereas comparative physiology deals with functional characteristics within large taxonomic categories, such as a kingdom or class. In special fields, such as medicine or agriculture, action must be designed with species characteristics in mind. But from an instructional point of view, and from a broad diagnostic or husbandry point of view, it must obviously be sterile to limit attention to those functional characteristics that distinguish species. There are about 66,000 living species in the phylum Chordata, of which about 15,000 are in the class Mammalia, and possibly 1000 are of immediate economic importance. The variations among species are too numerous to concentrate on them in instruction, in mobilization of first-order facts for the diagnosis of abnormalities or for cultural utilization, or in selection of research problems of greatest promise for efficient advancement of general biological knowledge. The encyclopedic detail of functional variation among species, even within the subphylum Craniata, must naturally parallel the known extent of morphological variations. However, many experienced physiologists have remarked the lack of a discrete "comparative physiology" to stand for students of animal function as comparative anatomy and comparative embryology have stood for students of classical zoology—this despite the existence of a textbook published in 1927 by C. G. Rogers,[1] of Oberlin College, entitled *Textbook of Comparative Physiology.*

The accumulation of facts about animal function seems now to have reached a volume and a completeness that justify emphasis on integrating principles such as those that have illuminated and accelerated investigations and understanding in anatomy, embryology, histology, cytology, and the classification of animals. That such principles can be recognized and utilized in the study of animal function is evidence of the maturing status of comparative physiology. Two textbooks have recently appeared dealing specifically, if differently, with this general approach—*Comparative Physiology,* by B. T. Scheer,[2] in 1948 and *Comparative Animal Physiology,* by C. L. Prosser[3] and collaborators in 1950; and the meeting of the Federation

of American Societies for Experimental Biology in Cleveland, Ohio, during September 1951, included a new section on the program of the American Physiological Society entitled "Comparative Physiology."

All areas of physiology provide examples in which the comparative approach has been especially fruitful in developing principles of its own, in supporting and clarifying broad biological principles, and in contributing to the knowledge of function in specific animals. Students of zoology are greatly aided and impressed by Darwin's theory of evolution. As my own interest in physiology developed, it was disappointing to learn how small were the specific, recognized contributions of this field in support of the theory. Textbooks of forty years ago could give broad and detailed evidence from comparative morphology through such principles as homology in locomotor appendages, central nervous system, aortic arches, kidney, and reproductive organs. Similar broad and detailed evidence was available from comparative embryology in the gross development of embryos, development of specific organs such as those previously enumerated, and the development of vestigial organs. Comparative physiology, on the other hand, offered only isolated, basically biochemical evidence.

The situation in modern textbooks of zoology has not changed. A more recent, widely used textbook of general zoology, for example, written by T. I. Storer[4] in 1943, gives essentially the same physiological evidence that was cited forty years ago. First mentioned are the classical studies of hemoglobin crystals published in 1909 by E. T. Reichert and A. P. Brown,[5] of the Department of Physiology at the University of Pennsylvania. They showed that the crystalline form of hematin was species-specific, that the form variations paralleled vertebrate classification based on the body structure, and that generic and even class similarity could be identified—the crystals from all birds had certain resemblances but differed from crystals obtained from mammals and reptiles. It has continued to be disturbing that this should be cited as "physiological evidence," because these crystalline differences were in no way correlated with function. The other evidence cited is of similar biochemical nature, including (*a*) precipitin tests of blood serum, the variations of which again are given no functional significance, and (*b*) the lack of species specificity of many digestive enzymes, such as trypsin. This is all the physiological evidence given, and it seems to typify the limited extent of the appreciation for comparative physiology, in general, among biologists. Such a limited view of the contributions of comparative physiology is quite unjustified by the amount of information and the extent of the principles that are developing in the field.

Some examples of the growth of comparative knowledge of function can be taken from respiration. Consider recent studies of hemoglobin. One method of gaining information about hemoglobin that is clearly of functional significance is to study its oxygen dissociation curves. Joseph Barcroft[6] first attributed significance to the fact that the blood pigment of a fetal goat[7,8] is a type of hemoglobin that takes up oxygen more readily than the maternal type of hemoglobin. On the other hand, the maternal type of hemoglobin gives up oxygen more readily than that of the fetus. He suggested that these differences displayed by the dissociation curves—which might be looked upon as functional profiles of the molecule—were correlated with the various ecological and physiological circumstances differentiating the aquatic, vegetative fetus from the atmospheric, animalistic adult. Subsequent work shows such a relationship to obtain in rabbits[9] and man.[10] This developmental-adult change in hemoglobin was also proved for cattle,[11] chickens,[12] and for amphibians and turtles.[13–15] In all the foregoing examples among the various classes of vertebrates, the hemoglobin has functional characteristics in the developmental stage differing from those in the adult, and the functional significance of these differences agreed with that suggested originally for the goat by Barcroft.

Differences similar to those between the specific oxygen affinity of hemoglobins in developing and adult animals have also been found between adults of different species within various classes. So far, comparisons have been made among fishes, amphibians, turtles, and a few birds and mammals. Hall and McCutcheon have called attention to the wide range of variability in the specific oxygen affinity of hemoglobin, to which important functional significance can be assigned. Of course, physiologists realize[16] that it is usually possible to infer logically consistent ecological adaptations between physiological variations and limited behavior or environmental circumstances, inferences that too often break down in significance when applied to large systematic groups. However, the extent to which hemoglobin variations among various species can be correlated with respiratory limitations of morphology, behavior, and environment is reminiscent of significant historical inferences of correlation between structural variations, function, and systematics—correlations which

characterized the useful principles outlined by such venerable observers as Cuvier in anatomy, Von Baer in embryology, and Darwin in evolution and environment. Among adult fish, for example, the sluggish toadfish, living in a poorly ventilated environment, has a relatively embryonic type of hemoglobin compared with an active mackerel, which lives in, and is confined to, a maximally ventilated environment. Other marine fishes, such as the scup, sea bass, tautog, and dogfish have activity patterns, environments, and specific hemoglobin affinities between these extremes.[17] Fully comparable correlations have also been found among thirteen species of amphibians.[18]

The weight of this accumulating evidence for significant correlation between the characteristics of a single molecular genus and the various cenogenetic and phylogenetic variations among animal species leads to the obvious conclusion that the same type of biological tendencies (e.g., genetic inheritance) which determines structural variations in animals also determines functional variations, and that the functional variations may be integrated into useful generalizations that can be recognized as adaptation, recapitulation, and evolution. Since these generalizations have already been established from morphological, developmental, and systematic studies, however, it need only be emphasized that modern comparative physiology offers discrete evidence for these principles.

Recently two studies in entirely different areas of physiology were brought together in a completely unanticipated manner to give mutual support to the importance of a comparative physiology. In December 1947, George Wald, of Harvard, wrote to me as follows:

> Some time ago—actually 1942—I was led by a situation which had arisen in connection with our studies in visual chemistry to examine the visual systems in the bullfrog, tadpole and adult. The story has now been published in the Harvey Lectures for 1945–6 so that there is no need to burden you with it now. What we found is that the photochemical system which governs stimulation in the retinal rods metamorphoses during the metamorphosis of the tadpole. In the tadpole the porphyropsin system is found, dependent on Vitamin A_2; while in the newly emerged frog this has been replaced by the rhodopsin system based on Vitamin A_1. The situation is so remarkable that I was most interested to find shortly afterward your paper on the comparable metamorphosis of hemoglobin in the same species.

Wald's[19] important work on photopigments involved comparisons over an extreme range of photosensitive plants and animals, from which he has been able to show that fresh-water vertebrates in general utilize the porphyropsin system based upon retinene and vitamin A_2, whereas vertebrate evolution either into the sea or onto the land led back to the use of a more primitive vitamin A_1 and the rhodopsin system. Interpolated between fresh-water and marine fishes are euryhaline forms which as adults can tolerate both environments—and they possess both systems, frequently in mixtures, and always predominantly the system appropriate to the environment in which the fish spawns. The paper on hemoglobin function during the life history of bullfrogs, which reported metamorphic changes, was published in 1936, but had apparently escaped Wald's attention, as his work had escaped mine up to the time of his quoted letter. The mutual support offered by these two distinct and separate comparative approaches for independently recognized evidence of a molecular evolution has been, to say the least, encouraging to a further search for the fruits of comparative functional studies.

A criticism often made of many physiology courses that emphasize vertebrates is that they are "frog and turtle" courses. An implied stigma results that reflects a growing general knowledge and use of mammals as laboratory material. But sight should not be lost, in this development, of the obvious historical—and instructionally significant—fact that much of the basic knowledge of muscle and locomotion or digestion, of heart and circulation, respiration, kidney and excretion, nervous and endocrine regulation—to mention the easily recognized—grew from studies of exactly such primitive vertebrate material. Primitive material will remain valuable in any course dealing with vertebrates, regardless of its ultimate special interest. It is a growing challenge and worth-while effort to make such studies (truly, comparative physiology). The viewpoint and objectives need only to be properly oriented away from concern with minute detail of individual species and toward concern with the basic functional mechanisms characteristic of the larger categories. Rogers[1] states the viewpoint or aims of comparative physiology as follows:

> 1. To give an exact and adequate conception of the essential nature of the various processes of the organism.
>
> 2. To make a comparison of these processes in different types of animals to discover whether they really operate under the same fundamental laws.
>
> 3. To trace, if possible, the course of evolution of these processes from the more generalized to the more specialized and complex.
>
> 4. To gain some idea, from the similarity of method employed by different groups of animals, of the possible relationship existing between them.
>
> 5. To show the correlation and integration of the various parts and processes in the economy of the individual.

The physiology of vertebrate excretion illustrates this viewpoint. The progress of the vertebrate kidney from pronephros through mesonephros to metanephros during embryonic and fetal development is classical comparative embryology. The structural variations of these organs and their distribution among vertebrates comprise classical comparative anatomy. Their physiological counterpart lies in such excellent studies of excretion as those by A. N. Richards[20] and collaborators, which began in 1915 with rabbit kidneys but turned back to a series of comprehensive experimental analyses of the amphibian kidney during the next fifteen years, before returning to the mammalian kidney. These studies provide an outstanding example of the growth and value of the viewpoint of comparative animal function—for when support was needed for conclusions about the importance of tubular secretion in urine production, the work of Smith[21] and Marshall[22] at an even more primitive level of vertebrate development, that of the bony fish, provided the necessary evidence. Starling's *Human Physiology*[23] says:

> Histological examination of the kidney tubules shows a great diversity of structure in the epithelium with which they are lined. Hence, it is quite conceivable that some portions of the tubule might absorb while other portions were capable of secreting: or the same cells might even absorb certain things and secrete others. Yet, for one or two decades, physiologists appeared to be so satisfied with the evidence in favour of reabsorption as to forget that the demonstration that urine formation could not be explained wholly on the filtration-secretion hypothesis by no means put that method out of court as an accessory.
>
> Once an instance had been produced of urine formation in which secretion indubitably played a part, the door was open to admit secretion as a possible collaborator with absorption, in the modification of the glomerular filtrate. Such an instance was produced when Edwards, Marshall, and Homer Smith, recalling the fact that certain fish had kidneys from which glomeruli were absent, pointed out that urine formation must in those species be a purely secretory phenomenon. Their future investigations on these aglomerular kidneys of at least twenty-five species of fish belonging to five different families have, more than anything else, provided the faith that was required for acceptance of the possibility of tubular secretion.

Convincing examples of the value of comparative studies—though often not intended as such—could be taken from many other segments of physiological interest, but those already given suggest certain generalizations about comparative physiology: (*a*) there are functional counterparts of all aspects of structural development and variation within systematic categories of animals which can provide integrating principles for physiology, provided a sufficient complement and distribution of facts are available for comparison, and provided their correlation is recognized (*b*) a truly comparative physiology can support the hypotheses about functions and can accelerate the productive search for facts about functions in a particular species; (*c*) morphological and classificatory correlations began with whole animals and progressed to organs and tissues, whereas physiological correlations and generalizations are more often recognized first at molecular, biophysical, and biochemical levels of organization and progress toward whole animals.

Morphological knowledge deals with form, substance, and class, whereas physiological knowledge deals with dynamics, rate, and regulation. The considerations of morphology are first of all spatial, those of physiology primarily temporal. For these reasons a viewpoint of comparative physiology can be recognized to have special advantages in gaining knowledge of animal function. Thus the advantages of the amphibian kidney in its relatively simple exchange and low magnitude of action guided the previously outlined work of A. N. Richards[24] and Homer Smith[25] to establish principles of kidney function, and the special limitations of the aglomerular kidney of certain fishes supported the investigations of the mammalian kidney.

Much attention has recently been given to the limitations of instrumentation and the refinement of instruments for physiological research.[26] Comparative physiology often has a great advantage in being able to select the animal to fit the limitations of instruments and techniques. The significance of limitations arising from the relative magnitude of processes was given clear expression by E. Newton Harvey[27] in 1928. He pointed out that the relationship of the concentration of oxygen at the surface of the cell, and its respiratory exchange rate as compared with the volume-surface area relationship ($C = Ar^2/6D$), limited the size of cells; for the diffusion gradient of oxygen necessary to maintain a constant, reasonable metabolic level is proportional to the square of the radius. In simple terms, the volume increases as a cubic dimension, whereas surface increases as a square dimension, so that surface area is the limiting factor in all exchanges between the protoplasm within the cell and the external environment. This fundamental relationship also pertains in a very significant way to comparative physiology, because important functional changes are basically related to surface areas, such as the respiratory area of the lung, the glomerular or tubular area of the kidney, the absorptive area of the intestine, or the exchange area of the capillary

and lymphatic beds. Little specific work has been done on such relationships within any class of animals, even Mammalia. But problems exist that might profitably be approached from this viewpoint.

It can be recognized that certain significant relationships of the total capillary surface to protoplasmic volume within given structures, such as the gluteus maximus muscles, could set limits to their growth or hypertrophy.[28] August Krogh,[29] in making basic contributions to knowledge of capillary physiology, measured the relative density and surface areas of capillaries in muscles of frog, horse, and dog. He found these to be, respectively: density, 400/mm^2, 1400/mm^2, and 2600/mm^2; surface, 190 cm^2/cm^3, 240 cm^2/cm^3, and 590 cm^2/cm^3. These data suggest that, as the structure increases in size, the capillary surface area may not maintain a proportionate increase. Thus, when mammals of such divergent size as a rat and a horse are compared, differences appear in the level of activity of muscles, the rate of diffusion and distribution of solutes through tissue, the relative volumes of body fluid compartments, and the like; all of which can be expected to have characteristics peculiarly related to this limitation of surface area to volume and metabolic rate. Furthermore, in a large animal, such as the horse, with a remarkable development of specific muscles of locomotion, this limitation may be extended to the point where definite failure of the circulation may occur under conditions of extreme hypertrophy and activity; failure and breakdown of the muscle tissues themselves may result. In fact, there is a specific disorder involving the large muscles of the hind limbs of horses that might be accounted for in this way. The disorder is called azoturia; the primary sign is a breakdown of the muscle tissue with the appearance of myoglobin in the blood plasma, and it seems to have no external causative agent.

An experience in our laboratory with the effect of varying blood calcium levels in cattle provides another example of rate-volume disparity. An injection of oxalate was being given to a cow in order to lower gradually the calcium concentration and calcium levels and study the effects on electrocardiogram, reflex responses, and calcium levels in urine. The total dose of oxalate had been calculated to be quite safe on the basis of some experimental work with cattle and a considerable amount of experimental work with smaller animals. However, the animal developed signs of calcium lack so precipitously that attempts to correct them were too late, and death intervened. The likely reason was that the rate of administration was too rapid in relation to the rate of distribution throughout the body fluids, so that unduly low calcium levels were momentarily developed in the blood, and subsequent experiments so indicated. Since the rate of injection had a considerable margin of safety, based on knowledge of work with smaller animals, the explanation follows that the over-all rate of distribution of such substances in animals differs considerably. Investigation of the relative volumes of the various body fluid compartments and the rate of distribution of solutes in mammals the size of horses and cattle might provide interesting and useful information when compared with smaller animals, such as dog and man, for which much information is already available. Monica Reynolds[30] is studying this problem with modern techniques.

Recent research experience in the fields of circulation and respiration further exemplifies advantages of the comparative viewpoint. David Detweiler[31] has been studying the normal and pathological electrocardiogram in horses. His attention has been drawn to the complexity of the *P* wave, as compared with that of man and smaller animals. It has a distinct notch in some of the usual leads, suggestive of two distinct components. The critical analysis of this characteristic indicates that it is, in fact, a reflection of the unusually large difference in time between the contraction of the right and the left auricle in this large heart. As for respiration, studies of breathing patterns[32] of a series of mammals ranging in size from mice to horses show marked differences in the cycles. Rhythmically recurring complex cycles occur with an increasing frequency in animals as the specific size of the animal decreases. Furthermore, the resting breathing cycle of horses is polyphasic. Work so far completed in analyzing these cycles has provided evidence that they are related to the great contrast in conditions between (*a*) ventilation of the lung, which varies markedly with specific sizes of the animal (rat tidal volume 1.5 ml; frequency 60/min; horse tidal volume 6000 ml; frequency 10/min), and (*b*) diffusion at the level of the alveoli, alveolar size being relatively uniform compared to the range of animal size.

For those who may be primarily interested in learning about a single species, comparative studies on breathing also demonstrate the advantages of bringing in evidence from studies of different species within that category, as was previously pointed out from kidney studies. Comparison at the extremes of exchange patterns in breathing shows exaggerated differences, which first called our attention to a new element, called a comple-

mentary cycle, in the breathing pattern of rats. Such cycles were then identified in a variety of mammals. The variations of breathing found in these comparative studies support a hypothesis that there is intrinsic regulation of the diffusion factors, including pressure, at the alveolar level. Whatever eventual proof may show for the significance of complementary cycles in such a specific mammal as, say, the dog, the fact is that this intrinsic property of a dog's breathing pattern has been overlooked up to the time that comparative studies brought it into consideration.

The various examples that have been cited to illustrate comparative physiology have been drawn from the vertebrates. Invertebrate physiology has also gained from, and contributed to, comparative physiology in many ways. Study of the giant axon of the squid has furthered knowledge of nerve physiology in all vertebrates; study of locomotion and taxic behavior in amebae has furthered knowledge of leucocyte physiology in all vertebrates; study of the heart of *Limulus*, the king crab, advanced knowledge of the vertebrate heart. Such examples could be repeated not only from every field of physiological interest in vertebrates but also from the personal experiences of many of the productive investigators in vertebrate physiology, as a reference to Prosser's *Comparative Physiology* will quickly show.

If comparative physiology has now become a recognized discipline, coequal with special physiology and general physiology, then those who concern themselves with the broad advancement of knowledge and learning in biological sciences should recognize its viewpoint and progress. Comparative physiology should be given proper place in the programs for students of general zoology, medicine, animal husbandry, entomology, ichthyology, ornithology, and all other special considerations of animals that attract the attention of biologists. More specific recognition, encouragement, and opportunities should be accorded students and investigators in this field by providing for distinct publication facilities and for separate discussion platforms at biological meetings. Thus, whatever virtues attend the recognition in fact of a particular intellectual approach and special area of activity in any scientific field will work to bring to biological sciences the proper rewards of rapidly expanding knowledge in comparative physiology.

Comparative physiology should no longer be a budding appendage on comparative anatomy, general physiology, special physiology, animal biology, economic zoology, and the numerous other titles to which its substance is now attached. Relieved of this generative bud, the parent subjects can concentrate more efficiently on the particular areas of knowledge characterized by their titles. Comparative physiology can then develop and flourish within its own resources.

References

1. Rogers, C. G. *Textbook of Comparative Physiology*. New York: McGraw-Hill (1927).
2. Scheer, B. T. *Comparative Physiology*. New York: Wiley (1948).
3. Prosser, C. L. *Comparative Animal Physiology*. Philadelphia: Saunders (1950).
4. Storer, T. I. *General Zoology*. New York: McGraw-Hill (1943).
5. Reichert, E. T., and Brown, A. P. *Crystallography of Hemoglobins*. Washington, D. C.: Carnegie Inst. (1909).
6. Barcroft, J. *Lancet*, **225**, 1021 (1933).
7. Huggett, A. St. G. *J. Physiol.*, **62**, 373 (1927).
8. McCarthy, E. F. *Ibid.*, **80**, 206 (1933).
9. Hall, F. G. *Ibid.*, **82**, 33 (1934).
10. Eastman, N. J., Geiling, E. M. K., and DeLawder, A. N. *Bull. Johns Hopkins Hosp.*, **53**, 246 (1933).
11. Roos, J., and Romijn, C. *J. Physiol.*, **92**, 249 (1938).
12. Hall, F. G. *Ibid.*, **83**, 222 (1934).
13. McCutcheon, F. H. *J. Cellular Comp. Physiol.*, **8**, 63 (1936).
14. *Ibid.*, **29**, 333 (1947).
15. Riggs, A. *J. Gen. Physiol.*, **35**, 23 (1951).
16. Krogh A. *The Comparative Physiology of Respiratory Mechanisms*. Philadelphia: Univ. Pennsylvania Press (1941).
17. Hall, F. G., and McCutcheon, F. H. *J. Cellular Comp. Physiol.*, **11**, 205 (1938).
18. McCutcheon, F. H. and Hall, F. G. *Ibid.*, **9**, 191 (1937).
19. Wald, G. *Harvey Lectures*, **41**, 117 (1946).
20. Richards, A. N. and Plant, O. H. *J. Pharmacol. Exptl. Therap.*, **7**, 485 (1915).
21. Smith, H. W. *Am. J. Physiol.*, **93**, 480 (1930).
22. Marshall, E. K., Jr. *Physiol. Revs.*, **14**, 133 (1934).
23. Starling, C. L. *Principles of Human Physiology*. Philadelphia: Lea & Febiger (1949).
24. Richards, A. N. *Proc. Roy. Soc.*, **126**, 398 (1938).
25. Smith, H. W. *Physiology of the Kidneys*. Lawrence: Univ. Kansas Press (1939).
26. Wood, E. H. *Science*, **112**, 707 (1950).
27. Harvey, E. N. *J. Gen. Physiol.*, **11**, 469 (1928).
28. Kety, S. S. *Pharmacol. Rev.*, **3**, 1 (1951).
29. Krogh, A. *The Anatomy and Physiology of Capillaries*. New Haven: Yale Univ. Press (1936).
30. Reynolds, M. *Federation Proc.*, **2**, 129 (1952).
31. Detweiler, D. K. *Ibid.*, 34.
32. McCutcheon, F. H. *J. Cellular Comp. Physiol.*, 37, 447 (1951).

SCIENCE ON THE MARCH

WHO GETS THE GRASS—MAN OR BEAST?

RAPIDLY increasing world population is intensifying the struggle not only between groups of men for areas of food production and resources, but also between man and other animals for the available food supply. In the case of the latter struggle, man, of course, dominates, and will continue to reserve more and more foods for his own use, especially the cereals and grains. Logically, it would seem that the foods allotted to other animals will be those less acceptable to man, such as coarser grains, roughage, and pasturage. Such a program would act incidentally as a selective factor favoring the existence of those animals best adapted to such feeds—possibly the ruminants. Seemingly, then, most animals will have to depend largely upon feed from grasses (including legumes).

At first this allocation of grasses to other land animals as their main source of feed might seem safe from the inroads of man. Recently, however, it has become increasingly evident that there will even be considerable competition between man and animals for at least a portion of the forage plants. Already in the United States, wheat, barley, rye, oats, and sudan grass, as well as alfalfa, are being cut and dried in the early stages of growth and packaged for both human and animal consumption. In fact, the 1950–51 U. S. Department of Agriculture Yearbook, *Crops in Peace and War*, states (p. 105) that the product is "a good vitamin supplement" for human use. Similar handling of other forages is now in the experimental state in this country—though various young green legumes and cereal grasses have been used for food in regions of the Near East for some time.

The key to the optimum use of grasses as human food apparently lies in harvesting and dehydrating them while they are still in the unjointed stage of growth. At this time grass vitamin factors, as well as protein content, are at their peak (Fig. 1). Moreover, once the first jointing stage is past, both vitamin and protein decline sharply with increasing maturity. Also, fiber content increases after the first jointing, whereas before the first joint is formed, the plant is tender, green, and succulent. Thus, one company processing grasses for human consumption has a policy of harvesting on or about the eighteenth day after the plants appear above the ground.

Actually, the very peak of healthful, life-giving nutrients exists for only a few hours near the time of the first jointing. This necessitates rapid harvesting and dehydration. How critical are both this period and the methods then employed, can be partially indicated, perhaps, by the grant of a U. S. patent (No. 1942943) applying to the dehydration of grasses prior to jointing.

Production in the United States thus far has been limited mainly to Kansas and Missouri in the Middle West, and to Louisiana and Texas in the South. This is partly due to production problems, such as the limitation to certain soils, availability of water at the right time and in proper amounts, the proper blending of the harvested grasses, and the cutting and handling of grasses at such an early

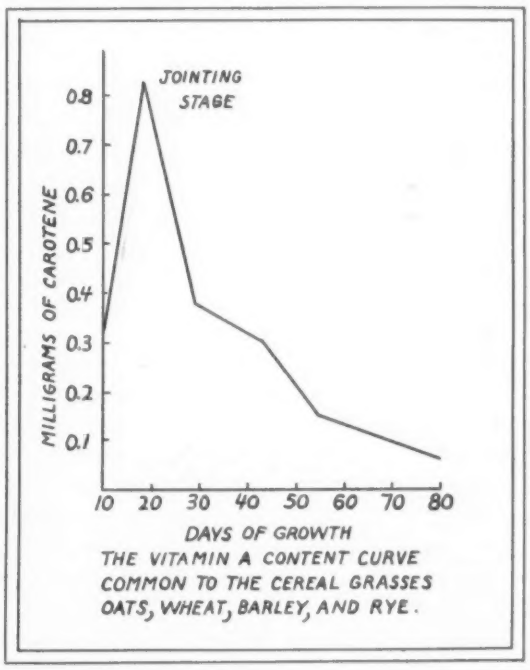


FIG. 1. The pattern for the rise and fall of other vitamin content in these grasses is much the same as that for vitamin A, as well as is the curve for protein content. Similar curves of nutritive content exist for many other grasses, though not all rise to such sharp peaks, nor decline quite so rapidly. (Data from Cerophyl Laboratories, Inc., Kansas City, Mo.) Perhaps man has erred for centuries in maturing grain for human use when consumption of the cereal grasses prior to jointing might well have provided a greater total supply of high-quality human food.

stage of growth. These have necessitated perfection of special equipment, and the development of laboratory tests in order to attain the uniform product so desirable for large-scale marketing. Extremely rapid flash drying, with exposures of up to 1800° F. for no longer than 2 minutes, has made possible minimal nutritional losses. Nevertheless, in some instances, synthetic B complex vitamins and vitamin D are added prior to preparation in powdered or tablet form for vacuum sealing in darkened containers.

Thus far, sale for human consumption has been largely through health food stores, but it seems likely that the trend may follow that of wheat germ, and the product may soon be available in the larger groceries as well.

The total eventual consumption of unjointed grasses in this country is quite unpredictable. It may well rise to a considerable amount, however, especially since dehydrated grasses eaten 15–30 minutes before a meal have a tendency to reduce the appetite. Such a characteristic, combined with low calorie content and abundant vitamins, should do much to popularize their use, especially by persons on weight-reducing diets.

Formerly, it was commonly contended that as man's needs encroached more and more upon the usual food supplies, domestic animals could be shifted to by-product feedstuffs, as well as to the coarser grains, roughages, and pasturage, but a recent examination of the present-day utilization of by-product feedstuffs reveals that many of these, too, are being diverted into industry on a large scale. Still others, such as brewer's yeast, dried skim milk, rice polish, and blackstrap molasses, are increasingly being included in man's diet. Thus far, the encroachment on by-product feedstuffs by man for his own immediate use is considerably greater than upon the nonleguminous and noncereal grasses. Today, even the security of these grasses for future domestic animal production is being opened to serious question.

CHARLES WILFORD JOHNSON
Mountain View, California

THE ROLE OF SOCIAL RESEARCH IN WORLD AFFAIRS*

THE findings presented here, from a recent survey of the actual and the possible applications of social research by governmental and nongovernmental agencies concerned with the improvement of international relations, individually provide no great surprises, but their total significance cannot fail to be of concern. In the first place, the investment of funds in such research has never been high. Between 1938 and 1948 the total estimated budget for all types of social research in the United States increased from 34 million to 88 million dollars. This seems but a pittance when compared with the budgets for research in the natural sciences, which grew from 234 million to more than 1,250 million dollars during the same decade.

Analysis of the items covered by social research budgets indicates the limited impact on problems of international relations that is possible under an allocation of funds of even 88 million dollars. Of the total amount budgeted for 1948, 27 million dollars was spent by business interests in the application of social science methods to business operations (economic research, market surveys, applications of psychological methods to personnel selection, analysis and improvement of worker morale, and other problems of management). Fifty-two million dollars was spent by the federal government for population data, employment and labor statistics, production and price data, and the like. Several additional millions were spent by the armed forces on projects directly related to the selection and utilization of military personnel, combat efficiency, and related problems of leadership.

Of the 5 or 6 million dollars spent for all other forms of social research, only a small fraction could be credited with any direct contribution to the improvement of international relations. Almost 2¼ millions of this amount was granted by the Rockefeller Foundation, of which only one seventh was for research in international relations. Most of the one seventh was granted for two long-time area studies. The inventory in public administration for the same year lists 716 projects, of which only three classify under "foreign relations" and six under "international organization and administration." The conclusion is obvious that very little money was invested during the decade prior to the rise of the present international emergency in types of social research that could be expected

* Based on a paper presented before Section I of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE at the Annual Meeting in Philadelphia, December 28, 1951.

to contribute to the improvement of world affairs.

The second conclusion is no more reassuring. Not only was the investment prior to the last two or three years very small, but the present international crisis has not given the same type of impetus to social research that it has given to physics, chemistry, and the biological sciences. In fact, it has tended to pull certain social scientists away from their previous research interests and to involve them in other activities. In times of national emergency the natural scientist intensifies his research activities, but the social scientist often abandons his research because he is needed in an administrative position, or there is a reduction in funds for research, or because of some other form of discouragement.

In the third place, the record indicates that the research of social scientists who were interested in international relations has been concentrated predominantly on a narrow range of problems. As asserted in a recent publication of the Social Science Research Council:

> Traditionally, research in international relations has been mainly the province of historians, students of international law and procedure, and diplomats. . . . But as yet sociologists, social psychologists, and social anthropologists—the social scientists most directly concerned with problems of behavior—have done little research on international behavior. . . . It is regrettable that the least effort of those engaged in studying the predictability and direction of human behavior probably has been expended in the field of international relations.†

There are many facts to substantiate this conclusion. There is also evidence, however, that the focal point of emphasis is gradually shifting and will continue to shift in the future. This shift is guided by a growing appreciation for the potential contributions of social research to an understanding of what might be called the "group dynamics" of world affairs. Limited application during past years has begun to inspire confidence in the possible value of wider application in the future.

The Value of Social Research in World Affairs

The actual and potential values of research utilization are becoming recognized in at least three broad areas of application:

a) The planning of certain governmental and nongovernmental programs that involve cooperation with other nations.

b) Official and unofficial efforts to improve international understanding and good will through impact on visitors who come to the United States from foreign lands.

c) Efforts to understand the causes of international conflict, emotional tension, and related phenomena.

Two illustrations will suffice to explain what is meant by contributions of social research methodology and findings to the planning of governmental and nongovernmental programs that involve cooperation with other nations.

We have the example of a great industrial firm, the Arabian American Oil Company, contracting with a group of social scientists to give the company expert technical guidance in its efforts to maintain and improve the quality of relationships with native employees and with the Arabian people as a whole. This program has been under way for some time but is now being intensified in order to prevent the type of conflicts that have arisen in other countries in the Middle East. During 1951 there was an initial survey of social, economic, anthropological, and psychological factors. This survey was made under the direction of Roy Lebkicher, of Arabian American Oil Company, and Douglas H. Fryer, of the consulting firm of Richardson, Bellows, Henry and Company.

The preliminary survey led to the setting up of an extensive plan by which psychological understandings and methods will be applied to the task of strengthening cooperative relations between the company, native employees, and the Arabian community. Participation of native Arabians in the administration and technical management of the company will be increased. Training programs have been in operation, but these are being reappraised and modified for the most effective education of leadership groups at various levels of management. A plan for continuous evaluation of the training programs is being instituted. Patterns of job classification and the requirements for progress from one job to a higher level are being established on an objective and psychologically valid basis in order to relieve native workers of their persistent fears that they are victims of discrimination in promotions. Problems of worker morale are being studied as the basis for programs of supervisory training and the improvement of worker-supervisor relationships. Special training problems, such as that of communication through the spoken and written word, are being approached scientifically. Through it all, there is the basic concern for the quality of personal-social relationships that exist wherever the two cultures, the American and the Arabian, meet.

These steps are being attempted in the setting of a culture that is devoid of many of the tools and objective social data that are taken for granted in America. For example, there are no Arabian psy-

† Donald Young. In the foreword to Otto Klineberg's *Tensions Affecting International Understanding*. Social Science Research Council, New York. 1950.

chological tests for the selection of individuals of high potential ability. Both general aptitude tests and measures of special abilities are being produced as a first necessity in the planning of personnel procedures.

The results of this application of social research techniques and findings by one company which thinks it is a good business investment may have broad implications for the United States in our efforts to assist other so-called underdeveloped areas.

It must never be forgotten that since the signing of the United Nations Charter on June 26, 1945, political independence has been given to nearly 600 million people, or nearly four fifths of the non-self-governing peoples of the world. Many of the problems of the world are new ones not subject to conventional solution, because of the political, economic, and psychological climate that has resulted from new-found freedom.

A second type of application of research methodology is illustrated by a proposal that originated in the thinking of Carl Remer and his colleagues in the Center for Japanese Studies of the University of Michigan—a proposal that has never received the financial support needed for full accomplishment. This proposal was for a cooperative study by American and Japanese social scientists of the economic and social development of Japan from the end of its international isolation until 1945. Japan represents the outstanding example of an underdeveloped country that used Western technical assistance in an effort to take its position among progressive nations. The results were in some respects good and in certain other respects almost disastrous to the world. Careful analytical study of the Japanese experience—their methods, successes, and failures—should give guidance to those responsible for planning economic and technical assistance for other underdeveloped areas. In view of the huge investments of American funds—both public and private—that are now being made, it becomes important for purely economic reasons to profit from careful study of past experiences.

Another example of research utilization illustrates possible contributions to both official and unofficial efforts to improve international understanding and good will through impact on visitors who come to the United States from foreign lands.

There are many programs involving international exchange of peoples. Students, representatives of the professions, businessmen, industrialists, and many others are coming to the United States for stays ranging from a few weeks to several years. The purpose of exchange programs is to modify the attitudes, the understandings, and the behavior of those who come to visit us, to the end that they may be more effective leaders in their own lands and thus contribute more effectively to world-wide understanding. All too often these programs are merely an act of faith. There is a minimum of objective data to indicate how much is contributed to the improvement of international relations, and to define the conditions under which interchange is advantageous or detrimental to individuals or to society.

The possibilities here are illustrated by certain recommendations recently prepared by the Institute for Research in Human Relations for use by the Office of Educational Exchange of the Department of State in planning a comprehensive evaluation of their program. It is proposed that a beginning be made with an analytical study of the type of people who come to America under State Department auspices and the type of experiences they have while in America. With this as a background, it is recommended that the best available techniques be used to discover what changes take place in understanding, and misunderstanding, of American institutions, concepts of American character and values, concepts of democracy, concepts of United States foreign policy, and the visitor's idea of his own role as an exchangee. Some information can be obtained from data gathered at the time the exchangee comes to America and by comparing it with other data obtained at time of departure. But this is not enough.

It is further proposed that there be a follow-up of groups of exchangees after their return home to find out what positions they hold; how they use the skills they came to the United States to acquire; how much influence they have in the socio-economic, political, or professional life of their native countries; and clues as to possible modifications of their experience in the United States which would have made a difference in the quality of leadership rendered after returning home.

As a further post-audit it is suggested that the exchangee program be validated within the frame of reference of American foreign policy for the years 1940–50. Such questions as the following are pertinent:

a) Were the selection of candidates, orientation, programming, and relations with exchangees after return so designed for each year as to implement that year's foreign policy programs of the United States?

b) With the benefit of hindsight, did the exchange program operate in areas and with people which events showed to be of prime strategic significance for the United States? (If, for instance, it is possible to see now that the left-of-center trade unions of a country have become

the most critical political group of that country, did we foresee that development and prepare for it by bringing to the United States key figures of those groups?)

What is proposed as an evaluation of the exchange of persons program of the Department of State would have significance for a great variety of other programs.

The third broad area of research, concerned with the causes of international conflict, emotional tension, and related phenomena, offers varied possibilities. They include American and British studies of the psychological effects of news releases regarding atomic and other unconventional weapons on the capacity of citizens to do sound thinking on international affairs. They include studies of democratic methods of leadership, ways of introducing such methods in countries not previously organized on the democratic pattern, and ways of inspiring followers with a deep sense of loyalty to democratic ideals and social organization. They include studies of that often-stated fear that American freedom will be lost during a prolonged state of war, and of the safeguards that could be established to avoid any such trend.

They include also a series of studies of domestic social tensions sponsored by the government of India in cooperation with Unesco and involving the social science departments of all Indian universities. They are investigating:

a) The attitude prevailing in three groups in the Bombay area and in Lucknow (Hindu residents, Hindu refugees, and Moslems) and the attitude of each of these groups toward the government's handling of the Moslem and refugee problems.

b) The attitude of the Hindu natives of Bihar toward refugees from East Bengal and toward Adibasi aborigines.

c) The personal reactions of Moslems and Hindus to the communal difficulties they have personally experienced in the last year or two (a study under joint Hindu and Moslem auspices).

d) The sources of distress and hostility among textile workers.

Coordinated Effort Necessary

The few illustrations that can be given in a short article can only serve to clarify what is meant by social research related to the "group dynamics" of world affairs. There is much evidence that the possible significance of such research is becoming recognized in many phases of leadership.

The other conclusions from the survey of actual and potential utilization of social research have to do with the requirements for effectiveness of research. These conclusions are based in part on the opinions of social scientists, and in part on the opinions of the potential users of needed social research. They are also based in part on the experience of the natural sciences in their approach to the solution of problems. One of these conclusions is presented here.

If we assume on the one hand that social research has a vital contribution to make to the cure of the world's ills, and on the other hand that a period of years will be granted in which the results of intensive effort could become manifest, then a rallying of forces not unlike that of the natural sciences in the development of the atomic bomb might be in order. More money would have to be invested in social research than ever before. Social scientists would have to turn their backs on attractive offers that would take them away from the research applications of their science. This would be necessary in order to achieve coordination of effort and resources on both an interinstitutional and an interdisciplinary basis, and in order to concentrate effort on projects of major size and significance.

Social research has often suffered from a piecemeal approach to questions that can only be solved by comprehensive projects. A fragmentary approach is the natural result when research personnel and facilities are limited in quantity and widely scattered among different agencies and institutions, or when there is no one group of researchers who have responsibility for carrying research to the point where definite solutions must be provided for real problems. The result has often been to emphasize trivia rather than fundamental problems, to be superficial in approach, to be wasteful of time and resources, and to be inconclusive in findings.

Coordinated investment of time, equipment, enthusiasm, and professional skill in comprehensive projects could not fail to lead to very wholesome outcomes. It would increase the probability that attention would be given to difficult problems as well as to those that are less complicated. It would encourage careful refinement of research methodology and techniques, and thoroughness in the exploration of alternative hypotheses. It would conserve money and facilities. It would conserve the time of researchers. It is a necessary step if social research is to play an increasingly vital role in world affairs.

KENNETH L. HEATON
Richardson, Bellows, Henry & Co.
Philadelphia, Pennsylvania

BOOK REVIEWS

MORE SOCIAL RESEARCH NEEDED

The Policy Sciences. Daniel Lerner and Harold D. Lasswell, Eds. xiv + 344 pp. $7.50. Stanford University Press, Stanford, Calif. 1951.

THE study of the role and formulation of both private and public policy is one of the most critical, though neglected, areas of research. Despite the ever-increasing complexity of the decision-making process in human affairs, the respective scientific disciplines to date have failed to merge their knowledge and methodologies to give an adequate picture of the development of social policy. *The Policy Sciences,* to which seventeen leading social scientists have contributed, is a pioneering effort to correct this situation. It is the first full-length volume of the Hoover Institute Studies, "a project studying the change in society since 1890."

Organized into three major sections, the book devotes the first six articles to the "Scope and Focus" of policy. The objective of this group of essays is to show the implications of social research for policy formation at all levels of the social order, including the individual, the group, the culture, the nation, and finally the world society. The second part of the book, consisting of five chapters, is primarily concerned with "Research Procedures" of the social sciences which may be utilized to analyze and clarify issues of policy and arrive at wise decisions. The last five essays, under the heading "Policy Integration," show a few of the ways in which policy analysis can be applied and the role of both the natural and the social scientists in this process.

Although not all the essays are as well integrated as might be desired, the book is dominated by the theme that social issues must be dealt with more scientifically and methodologically. It makes clear that unless this is done the essential ingredient of policy—namely, predictability—will not be achieved. A premium is put upon those methods of measurement which clarify trends and expectations for the future. The book also has a strong bias in favor of promoting social research that can be usefully applied in solving the problems of mankind.

With these laudable objectives and approach one can have no quarrel. Some major reservations, however, must be raised by this reviewer. First, although it is true that the book includes contributors from most of the social sciences, the evaluation is heavily weighted in favor of those disciplines dealing with social behavior —psychology, social relations, and kindred fields. Insights into the policy-making process derived particularly from economics, political science, and public administration have not been adequately represented. Second, a fetish throughout the volume for quantitative methods leads to insufficient recognition of other tools of social inquiry. Finally, no clear distinction is made between policy-making as a governmental vis-à-vis a nongovernmental function. Granted, many of the elements of policy-making are the same in both private and public spheres, nevertheless it is precisely the differences that are so important for consideration. These criticisms notwithstanding, there is no doubt that this work goes far toward establishing policy-making as a master science, a discipline that cuts across a number of subject-matter fields and becomes thereby a pivotal instrument for social analysis.

ERNEST A. ENGELBERT
Department of Political Science
University of California, Los Angeles

GRASSLAND CONSERVATION

Range Management: Principles and Practices. Arthur W. Sampson. xiv + 570 pp. Illus. $7.50. Wiley, New York; Chapman & Hall, London. 1952.

ARTHUR W. SAMPSON was trained in plant ecology at the University of Nebraska in the time of F. E. Clements, then spent five years (1907–12) in the U. S. Forest Service, ten years (1912–22) at the Great Basin Research Station, and since has taught range management in the Forestry Department at the University of California at Berkeley. His first book, on *Range and Pasture Management,* was published in 1923. The publisher's blurb on the dust jacket of the present volume calls him "the father of range management," and the book is a completely new work, not a revision. The twenty-four chapters are grouped into four parts: Range Management Perspective, Native Range Forage Plants, Improvement and Management of Range and Stock, and Protection of Land Resources and Range Livestock. So far as principles are treated separately from practices, they appear mostly in Part One, and in this group Chapter 6 is devoted to Historical Development of Grazing in America. The author's preface emphasizes his intention "to balance considerations." Referring to the chapter bibliographies, Sampson says (p. viii): "Collateral readings of selected current Federal and state publications are recommended to broaden the student's knowledge as a whole." The selection is not quite that limited. In general the execution of the book measures up to the statement of intentions sufficiently to assure it a position among the leaders in its field.

The objectives of the work include both principles and practices, two quite different things. In the field, the range manager is interested primarily in descriptions of accepted practices, and he does not necessarily inquire into the questions of why and whether they are sound. In the discussion of principles, these latter questions are the major concern. Standard textbooks tend to oversimplification, to statements of conclusions as

settled facts, and to studied avoidance of controversial involvements. As a result, readers may remain uninformed about basic issues. Professor Sampson is committed to the Clementsian–USDA school of ecology, and declares explicitly (p. 363, note) that Clements is "deservedly called the 'father of American plant ecology. . . .'" The history of American ecology has not yet been written, but when it is done the honors will be distributed generously among a considerable number of founders. The day of reckoning and re-examination of principles at the hands of the younger generation is long overdue and may be nearer than some think, as is evidenced by F. E. Egler in "A Commentary on American Plant Ecology . . ." (*Ecology*, **32**, 673 [1951]). These differences have a direct bearing upon ecological principles and their application, and the re-examination of concepts and principles should be extended to animal ecology and to soils.

The inclusion of a chapter on the history of grazing in America is in itself significant, in spite of the deficiencies in subject matter, map, and bibliography. The reviewer's hope is that such interest will be extended, because the time perspective has an important bearing on the objectives of such a book.

Even though the weight of pedagogical reasoning may be against introducing the student to the full extent of the differences among specialists, it does seem that college students are old enough to know some of these facts of life. As a minimum, could not a substantial selection of problem-projects be set up, with sharply focused questions aimed at re-examination of fundamental concepts and principles, together with adequate bibliographies citing all shades of opinion? Such collateral reading might effectively accomplish Sampson's objective, "to broaden the student's knowledge as a whole."

James C. Malin

Department of History
The University of Kansas

AMERICAN VIRTUOSO

Thomas Jefferson: Scientist. Edwin T. Martin. x + 289 pp. Illus. $4.00. Schuman, New York. 1952.

MOST of us have known from our school days, and from subsequent reading in political history, that the third President of the United States was interested in gadgets. The truth of the matter, that Jefferson was a fine scientist, is ably demonstrated in Dr. Martin's book. He has studied Jeffersoniana for many years and reports here on his well-documented findings. Insofar as is possible, politics are omitted and emphasis is placed on the valuable contributions to science.

The outstanding thing in the book is its revelation of Jefferson's foresight concerning aeronautics, submarines, torpedoes, mass production, and many other matters. For instance, he was interested in a way to turn sea water into fresh water—a quite recent modern development.

He stressed the importance of utility in science—his own and others'—so that he worked to improve agriculture, botany, medicine, chemistry, inventions of every conceivable kind, meteorology, and paleontology (but not geology—it was unimportant to him how old the earth might be).

As he traveled, he made notes and drawings of everything he saw, even making special trips to witness something new. He believed in the international dissemination of scientific findings, visited distinguished scientists abroad and received numbers of them as his guests at Monticello. One of his directing principles was that "the scientist has not only a right to freedom of inquiry . . . but a necessity to exert this right at any and all times." His scientific activities were the source of political attack and, conversely, of acclaim. He was proud to be president and an active member of the American Philosophical Society; a long list of other societies—here and abroad—of which he was a member, is given.

He announced that he was an amateur in science. Certainly he was in error in some of his conclusions but never in error in his scientific interest. His work produced "a greater humaneness in society, a greater tolerance in religion, a greater spirit of freedom for scientific inquiry."

Marjorie B. Snyder

Washington, D. C.

BIRDS SOUTH OF THE BORDER

Mexican Birds: First Impressions Based Upon an Ornithological Expedition to Tamaulipas, Nuevo Leon, and Coahuila, with an appendix briefly describing all Mexican birds. George Miksch Sutton. 282 pp., 16 color plates, and 65 pen-and-ink drawings by the author. $10.00. University of Oklahoma Press, Norman. 1951.

THIS is the story of a field naturalist at work on an expedition that has unleashed him in a new fauna and flora. The naturalist happens to be a seasoned ornithologist of great repute and a distinguished bird-artist, but this in no way dampens his enthusiasm for new experiences nor sullies the keenness of his observations. Rather, it augments his powers as a writer and enables him to convey the excitement of his discoveries until the reader tingles at the mere mention of some strange bird or weird call that has fascinated the author.

The first part of the book (186 pages in 32 numbered parts) deals entirely with a ten weeks' expedition into northern Mexico, such as any bird-minded tourist might make. The author and his colleagues, Thomas D. Burleigh and the late James B. Semple, did not venture very far from the Pan-American Highway, but they certainly found bird-adventure aplenty and made every minute count. Places like Mesa de Chipinque and Santa Rosa near Monterrey and the Rio Sabinas near Victoria, which barely register on ordinary maps of Mexico, certainly will be circled in red hereafter by any ornithological traveler planning a trip south of the border.

The reviewer has been particularly impressed by the author's phonetic interpretations of the many unusual bird songs and calls and his short, snappy descriptions of the birds themselves, which in a few words give a faithful picture, not only of the birds' colors, but of their behavior as well. His descriptions of the mountains and deserts, the rain forests, the natives, and his own exhilaration are equally vivid.

Interesting as is the first part of the volume, the appendix of 70 pages may be even more useful to a bird-lover planning a trip into Mexico, for it lists and briefly describes all the species that have been reported from Mexico, and for which there is, as yet, no convenient handbook. About 750 species are included in the appendix, of which some 350 do not get north of the Mexican border. The species found in the United States and covered by various handbooks are merely mentioned, but the Mexican species are briefly described and helpfully compared among themselves, with notes as to where they occur. They are arranged in their families in the customary phylogenic order, but there is no discussion of the families. Ornithologists, familiar only with North American and European birds, will find fifteen new families listed for Mexico, not included in their familiar handbooks, and they doubtless would have appreciated a short paragraph in the author's graphic style, telling them how to distinguish a honey-creeper from a warbler or a woodcreeper from an ovenbird or an antbird. However, the 65 lifelike drawings of typical members of each family go far to make up for this desideratum, and the 16 beautiful color plates not only make the volume more attractive, but likewise help the reader to feel familiar with birds of which he may thus far have only dreamed.

Since this is the first handy volume dealing with the birds of Mexico, it should go far toward stimulating more interest in the birds along the Mexican highways, and lead to the preparation of handbooks comparable to those available to bird students for the birds of United States and Canada.

A convenient, 23-page index lists all the birds considered in the text, both by common and by scientific names.

ARTHUR A. ALLEN

Department of Zoology
Cornell University

IN SEARCH OF RAPPROCHEMENT

The Integration of Behavior. Volume I: *Basic Postulates.* Thomas M. French. xi + 272 pp. $5.00. University of Chicago Press, Chicago. 1952.

MANY discussional battles have been waged by adherents (some might more accurately be called disciples) of the pro- and antipsychoanalytic camps. These generally result in more heat than light and in most cases are devoted to the merely negative purpose of disproving the opposition. Recent years have seen some cessation of this warring in favor of a more dispassionate approach to differences of opinion, with emphasis on ways of reconciling such differences. One such method is to examine the degree to which the "cognitive maps" of the pro- and anti-forces do, or might be brought to, overlap. The common goal of both camps is to obtain a better understanding of the dynamics of behavior; the dispute between the two has centered around the possible paths to follow in obtaining this understanding.

Dr. French, whose book is considered here, is associate director of the Chicago Institute for Psychoanalysis. A well-known psychiatrist, he is one of those willing to concede that the gospel according to Freud may not contain all the answers. In this book he attempts to provide an explanatory integration of psychoanalytic theory with learning theory by presenting facts and documentation attained through a detailed analysis of the thoughts, acts, and dreams of one person during two years of psychoanalytic treatment. The *rapprochement* sought involves an attempt to harmonize the views of Freudian or neo-Freudian doctrine with ideas about the learning process as presented by Pavlov (conditioning), Köhler (Gestalt insight), Lewin (field theory), and Tolman (purposivism and cognitive maps).

The purpose of this synthesis is to shed new light on how elementary human reactions are acquired and combined into coordinated and meaningful behavior patterns. As Dr. French says,

> . . . starting with the common-sense notions of motivation and insight, we shall try to construct a picture of the integrative apparatus and how it works and shall check this picture against the clinical data of our case history. We assume as our working hypothesis that rational behavior and neuroses and dreams have much in common and that in irrational behavior we should find fragments of the integrative mechanism that we must postulate to account for rational behavior.

(The question of why working from irrational to rational behavior is preferred to working from rational to irrational is not considered.)

Discussion in the book is organized under the following section headings: (1) Problem and Method, (2) Systematic Analysis of Common-Sense Assumptions, (3) Integration and Disintegration of Purposive Behavior, (4) Effects of Frustration, (5) Present and Past, (6) The Modifying Influence of Sleep, and (7) Reconstruction of the Integrative Process.

The present volume, the first in a series of five, is concerned with presenting the basic postulates. Subsequent volumes are to provide further examination of the integrative process as revealed in clinical data. It is to be hoped that in these volumes the anchoring and amplification of the integrative process will be supported not only by an analysis of clinical data but also by other relevant approaches to the problem. In this first volume, the effect to demonstrate how the various contributions to an understanding of the integrative process overlap has been more successful in the theoretical discussion than in its application to the interpretation of clinical case material.

Dr. French has done a big job in laying the ground-

work. The task of completing the superstructure will be an even larger one—one that is sure to be watched with interest.

GEORGE F. J. LEHNER

Department of Psychology
University of California, Los Angeles

HYPOTHESES IN COLLISION

The Planets: Their Origin and Development. Harold C. Urey. xvii + 245 pp. $5.00. Yale University Press, New Haven, Conn. 1952.

IT IS a significant event for such a noted chemist as Dr. Urey to turn his attention to the planets and their origin and development, for, as he states: "Much of the detailed knowledge of all physical sciences is necessary, directly or indirectly, for an understanding of the origin of the solar system." The book contains a mass of information that alone would make it valuable.

Dr. Urey attempts to explain the chemistry and physics involved during the evolution of the proto-planets of Kuiper's dust-cloud hypothesis into the planetary system, with a loss of 97–98 per cent of the mass of the proto-planets. He adds the postulate that planetesimals, silicate, and iron objects much like the present meteorites, condensed with the developing planets, formed the main masses of the terrestrial planets and the moon. At the right temperatures and pressures, liquid water and ammonia, by wetting cosmic dusts and condensing silicates, made them sufficiently "sticky" to coalesce into planetesimals.

One might wish that Dr. Urey had been more skeptical in reference to information, had correlated and evaluated it more carefully, and had been more familiar with celestial mechanics, for there are far too many errors and inconsistencies in his treatise.

Perhaps one difficulty is that he is attempting to develop a basically untenable hypothesis, for, in common with all evolutionary hypotheses, angular momentum, as ter Haar wrote in 1948, ". . . seems to present unsurmountable difficulties."

Among the errors and inconsistencies in Dr. Urey's speculation the following might be mentioned. The proposed mechanism to account for the escape of terrestrial mercury seems impossible, and that to account for the enormous depletion of neon, both obscure and inadequate. The velocities assigned to planetesimals that hit the moon are incompatible with celestial mechanics. The argument to show that the Disco iron and the small specimen of native iron in nearby basalt proves the existence of subterranean metallic iron is inconclusive. The suggested degasification of iron meteorites by close approach to the sun is impossible unless meteorites were formed near or within the orbit of Mercury. The suggestion that solar radiation dissipated the excess materials of the proto-planets is questionable for reasons of the conservation of momentum. The assumption that meteorites are planetesimals formed in the proto-planets seems less consistent with observational data than the usual assumption that they are fragments of an exploded planet. The statement that Kant's hypothesis was rejected for inadequate reasons seems to be unfounded, for its rejection was due to its failure to account for angular momentum.

In a sense it seems futile to consider hypotheses of the origin of the planets that fail to account for the distribution of angular momentum in the solar system. Russell-Dugan-Stewart's statement, written in 1926 is still true, that no process has ever been imagined to account for angular momentum in evolutionary hypotheses. In January 1951, ter Haar wrote this reviewer:

> I have suggested electro-magnetic effects may have been responsible for the slow rotation of the sun. I do not attach much importance to this speculation. I would like to stress . . . the difficulty is the slow rotation of the sun. One has to find a mechanism which slows down solar rotation!

Finally, Whipple wrote the reviewer on March 26, 1952: "The general tendency at present, as you will note in Kuiper's discussion, is to ignore the whole problem of residual angular momentum in the sun and to assume that, since stars like the sun have low rates of rotation, there must be some other process at work."

P. S. PALMER

125 N. W. 60th St., Miami 37, Florida

HANDBOOK FOR TRAVELERS

Geologic Guidebook of the San Francisco Bay Counties: History, Landscape, Geology, Fossils, Minerals, Industry, and Routes to Travel. 392 pp. Illus. $2.50. California State Division of Mines, San Francisco. 1951.

THIS guidebook is divided into seven parts, comprising thirty-two separate papers. The spirit of cooperation that made the volume possible is emphasized by the fact that twenty-eight separate authors from many different organizations and institutions contributed to this work, which was produced under the supervision of Olaf P. Jenkins.

First, several criticisms are in order: (1) The guidebook professes to be for the general public, but at times abounds in technical language. (2) A large nontechnical map with all place names mentioned in the text would have been desirable. (3) A diagram showing all formation and stage names used might have been helpful. (4) There is repetition between some articles, and others contradict one another in minor details. (5) A few writers used their articles to propound favorite theories, and some of the sections, such as that on fault history, could have been expanded. (6) Though the book is primarily geological, a short essay on local botany and zoology might have been included. (7) The index is incomplete.

The over-all effect, however, is extremely pleasing. The regional history by Dorothy Jenkins gives a background that is never lost. All the historical accounts enhance the area's unique setting. Landscape history, geologic history, and prehistoric life sections, though

technical at times, are interesting and, in general, clear. Although fourteen of the thirty-two papers are devoted to the mineral industry, one does not feel that the subject is discussed at too much length. The section on water is well written, but arouses the desire to know more. In the final section, the guided tours along the region's major scenic highways will provide pleasant trips for many Sunday travelers. This guidebook has already attracted wide interest in the Bay Region, and serves not only as an aid to the layman, but also as a tribute to the interests of the Division of Mines of the State of California.

ARTHUR A. MEYERHOFF

Palo Alto, California

BRIEFLY REVIEWED

Electrical Communications Experiments. Henry R. Reed, T. C. Gordon Wagner, and George F. Corcoran. xix + 621 pp. Illus. $8.50. Wiley, New York. 1952.

THIS is a carefully arranged selection of experiments to carry the student in communications engineering through about four semesters of work in circuits. The book has four parts, with fifteen experiments in each part, treating in sequence the topics "D-C Fundamentals," "A-C Fundamentals," "Engineering Fundamentals," and "Radio Engineering." Schools using this text would therefore require no other laboratory manual in circuits until students reach the topics of antennae, industrial electronics, and ultra-high-frequency phenomena.

The outstanding feature is that the theory underlying each experiment is presented in compact but clear form as an integral part of the laboratory work. This gives the student something specific to study in preparation for the laboratory and shortens or perhaps obviates the usual preliminary laboratory lecture. Another good feature is the regular durable book binding consistent with the student's other books.

Because of the present trend toward considering communications as essential to nearly all branches of engineering, these experiments might also be recommended for power majors in electrical engineering.

An adverse but perhaps unimportant criticism is that the authors do not quite follow through on the publisher's cover statements regarding material on uncertainties in electrical measurement. Some discussion of measurement errors is given in an introductory chapter, but it is doubtful that sophomores could follow the argument. This is better than ignoring the subject, however.

The experiments seem to give a great deal of value for the budget dollar.

J. M. CAGE

Department of Electrical Engineering
Purdue University

Algae of the Western Great Lakes Area. G. W. Prescott. xiii + 946 pp. 136 plates. $10.50. Cranbrook Institute of Science, Bloomfield Hills, Mich. 1951.

AMERICAN students of fresh-water algae have long needed a book where descriptions are carried to the species. Since the vast majority of species of fresh-water algae are of world-wide distribution, Prescott's treatise, although limited to the algae of Michigan and Wisconsin, will be of great service to phycologists in all parts of this country and in other countries.

The book begins with two introductory sections entitled "Geographical Features and Algal Distribution" and "Relationships of Phytoplankton to Lake Productivity." The major portion of the book is devoted to the various divisions (phyla) of algae, with descriptions and keys for classes, orders, families, and genera of each division. For each genus there is a key to the species, and a description and one or more illustrations of each of the species. The illustrations, many of which have not been published before, are of high quality, and their accuracy should aid materially in identifying species unknown to those using the book.

The systematic section is followed by a comprehensive key for all genera of the area. Included in the key, and designated by asterisks, are certain genera that might be expected to occur in the area, but which thus far are unreported. In the index each species has a reference both to the page on which it is described and the plate on which it is illustrated.

This book is the summation of many years of work by Professor Prescott in Michigan and Wisconsin. It is a scholarly product by a competent authority who bases his descriptions upon firsthand knowledge gained from a study of living specimens.

GILBERT M. SMITH

Department of Biological Sciences
Stanford University

Urine and the Urinary Sediment. Richard W. Lippman. xii + 128 pp. Illus. $7.50. Thomas, Springfield, Ill. 1952.

DR. LIPPMAN'S manual and atlas succeeds in its principal aim—to contribute a collection of color photographs of urinary sediments, "which preserve subtle differences in shade and refraction that make the reproductions recognizably similar to actual microscopic observations." One may question, for example, whether an occasional blob in a field is actually a "cast," but all will find the 56 color plates highly attractive—most of them of surpassing excellence. Although the brief and helpful text is not otherwise remarkable, the book has considerable pedagogic value for students, as well as practical and aesthetic value for physicians. It consists nominally of 128 pages, counting color plates, legends, and blank pages, and may seem to some overpriced.

A. V. WOLF

Department of Physiology
Albany Medical College

Under the Sea Wind. Rachel L. Carson. 314 pp. $3.50. Oxford University Press, New York. 1952.

THIS is a reissue of the 1941 edition with less foreword and fewer illustrations and without change in pagination. According to an obscure note on the back of the title page, this edition is "with corrections." These have not been made in the glossary, which would have profited from an overhauling. Although simplification may be desirable in a popular book, too many of these definitions are simply bad or careless zoology. Another unfortunate feature of this new edition is the manner in which the publishers have played down the information that it is actually a reissue.

JOEL W. HEDGPETH
Scripps Institution of Oceanography
La Jolla, California

The First Book of Snakes. John Hoke. 69 pp. Illus. $1.75. Watts, New York. 1952.

AS INDICATED in the title, this is an elementary discussion of snakes in general. Well written, in a simple style, and attractively illustrated with numerous drawings, some in color, it has a great deal of information on the life histories and habits of different kinds of snakes, poisonous and nonpoisonous. The chapter entitled Don't Believe It refutes popular myths and false beliefs about snakes. There is a chapter on Snakes as Pets.

All in all, it is interesting, good reading for the juvenile, and I have an idea that the average parent, reading the book over the boy's shoulder, will learn more about snakes than he ever knew before.

W. M. MANN
National Zoological Park
Washington, D. C.

The Living Tide. N. J. Berrill. 256 pp. Illus. $4.00. Dodd, Mead, New York. 1951.

THE LIVING TIDE is an entertaining account of the seashore life of our eastern coast from Newfoundland to the Gulf of Mexico. Dr. Berrill tells of his experiences in a simple, straightforward manner, so that the layman unfamiliar with the ocean and biology will be able to follow the stories with comparative ease. Sharks, seals, and cod—jellyfish, snails, and shrimps—all are introduced to the reader in fascinating detail. Although the book is, in a sense, for the novice, there are many accounts, such as the history and distribution of the horseshoe crab and the reproductive cycles of the oyster and the jellyfish, which will be of interest to the advanced student.

Although the book is quite readable, Berrill's style lacks the smoothness and imagination of such contemporary writers as Gilbert Klingel, Rachel Carson, and William Beebe. But the author's long experience with marine life and his choice of subjects far offset this drawback. Berrill's scientific facts are for the most part accurate, although this reviewer is qualified to judge only the sections dealing with mollusks. The life of the clam, snail, and squid are presented in an entertaining and factual manner, but some students of mollusks may question his belief that moon snails (*Polinices*) are hermaphrodites, or that they bore through clam shells with the aid of acid.

R. TUCKER ABBOTT
U. S. National Museum
Washington, D. C.

Caravan: The Story of the Middle East. Carleton S. Coon. viii + 376 pp. Illus. $5.00. Holt, New York. 1951.

THIS volume's main interest is the Islamic way of life. Dr. Coon thinks that we of the West are today faced with problems the East has already solved—the problems of diminishing resources and increasing population—and that we should therefore look eastward for such wisdom as we may acquire. Civilization came from the East, but we have forgotten, he thinks, one of its fundamental tenets.

The principle that we have forgotten, the principle that welds Islam into a flexible, enduring equilibrium—which he fears we will irrevocably upset with our mechanized industrialism—is that of specialization of function. Every individual in the Middle East—however low or however high his status, however intelligent or however dull his wit—is skilled in one thing, and that one thing he does with skill. Coon says that the system of a society must be right. If the system is right we can survive our other foolishnesses; if the system is wrong our other virtues cannot save us. He seems to be at a loss in accounting for this wisdom of the East. I am therefore tempted to point out that the theory of the division of labor is Plato's theory of justice in the *Republic.* Nor does Plato claim to have made a discovery; he was attempting, as Dr. Coon is attempting, to recall to his erring people their inherent although forgotten wisdom.

This is only the essence of Dr. Coon's book, the theory. Its bulk describes the division of labor in practice, with much relevant information. The Middle Eastern people are a homogeneous race, the Mediterranean. He has measured their skulls, their jaws, legs, and spines, and knows the color of the skin under their arms. What the psychologists do not know about us the anthropologists apparently do. The country of the people whose armpits are pink boasts three kinds of deserts, several religions, a modicum of rainfall, and the ideal situation of being at the crossroads of the world.

It is social organization that chiefly concerns Coon: the relation of villages to nomads, of nomads to civilization, of towns and cities to caravans, of aristocrats to slaves. This cuts across many fields, not the least of which is history. Muhammad strides into the pages, and so does Hulagu. I believe Dr. Coon to be right: Westerners should step outside their own world, at least long enough to read this book and learn something of values other than their own.

HUNTINGTON CAIRNS
National Gallery of Art
Washington, D. C.

PACIFIC DIVISION · AAAS
Thirty-third Annual Meeting
June 16–21 at Oregon State College, Corvallis

Memorial Union Building, Meeting Headquarters

OLDEST of the geographic divisions of the AAAS, the Pacific Division embraces the states of California, Nevada, Oregon, Washington, Idaho, and Utah; it reaches across the international boundary to include British Columbia and beyond the continental limits of the U. S. to take in Hawaii. Until Alaskans set up their own division in 1951, Alaska was also part of its domain.

The division was established in 1915 to serve the needs of the rapidly increasing number of scientists in the Far Western states, and it has consistently functioned as a service organization. Typically, at Corvallis, the division's program will consist of a symposium on basic research in relation to agriculture and forestry, a picnic supper on Mary's Peak, and three evening addresses: F. W. Went will speak on "Climate and Plant Growth;" H. A. Spoehr, president of the division, on "Society in the Grip of Science;" and Henry Eyring, on "Some Important Chemical Reactions in Agriculture and Forestry."

The rest of the meeting consists of sessions of affiliated and associated societies. The American Chemical Society has scheduled a Pacific Northwest Regional Meeting under the direction of its Oregon Section. The Oregon State College Branch has arranged a day of sessions for the American Meteorological Society. The American Phytopathological Society will meet two days and spend Saturday in the field. The Western or Pacific sections of the American Nature Study Society, the American Society of Horticultural Science, the American Society of Ichthyologists and Herpetologists, the American Society of Limnology and Oceanography, the American Society of Plant Physiologists, Botanical Society of America, Ecological Society of America, Society of American Foresters, Society of Systematic Zoology, and the Biometric Society have all arranged annual or regional programs of considerable significance. In addition, the Herpetologists League and such regional organizations as the Association of Pacific Coast Geographers, the Cooper Ornithological Club, Pacific Northwest Bird and Mammal Society, and Western Society of Soil Science will hold full-scale meetings.

The time of the meeting and its setting in Oregon's fertile and populous Willamette Valley offer every inducement to attend the Pacific Division's 1952 meeting. Additional information may be obtained from Robert C. Miller, California Academy of Sciences, San Francisco, or from Leo Freidman, Oregon State College.